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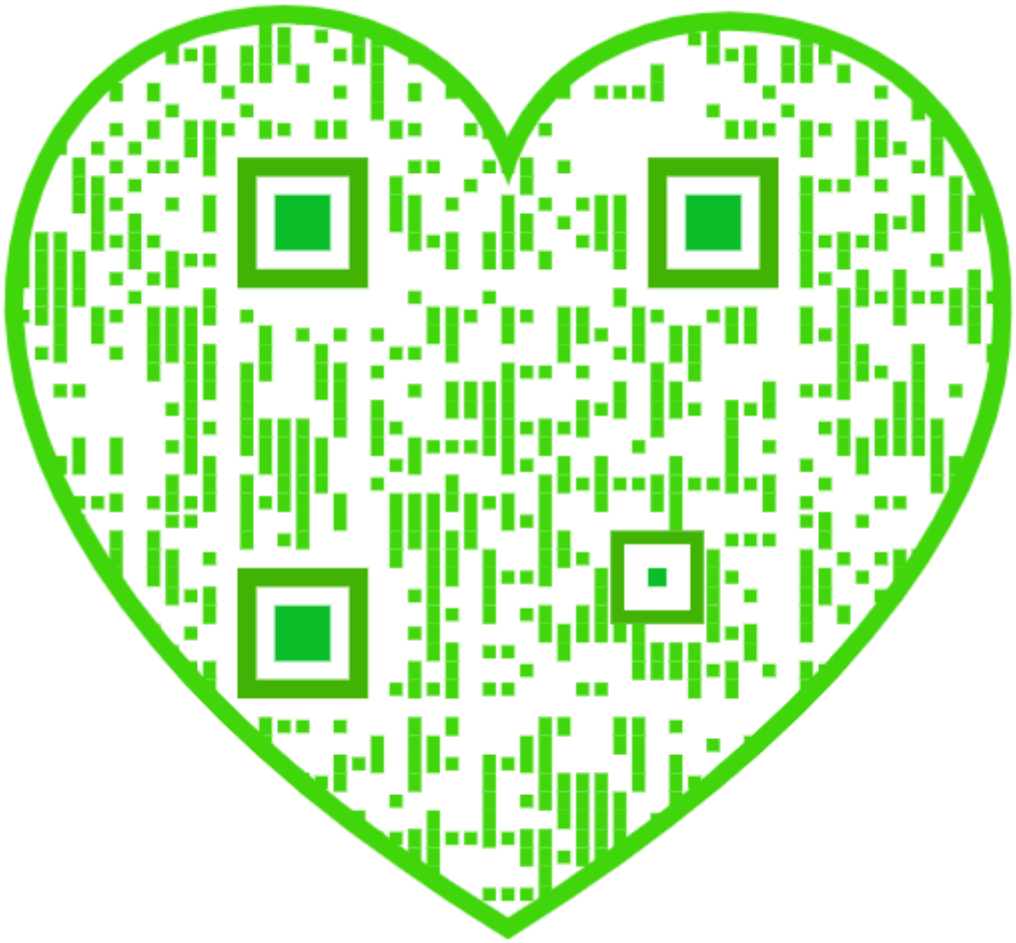
HAND-BOOK
FOR
OPTICIANS.



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HAND-BOOK

FOR YOUNG AND OLD

OPTICIANS.

A CONCISE AND COMPREHENSIVE TREATISE ON THE THEORY OF THE OPTICAL TRADE AND OF ITS MECHANICAL MANIPULATIONS.

AN INDISPENSABLE COMPANION TO ALL PROGRESSIVE CO-LABORERS

OF THE

OPTICAL TRADE,

CONTAINING MANY POINTS HERETOFORE UNEXPLORED AND UNEXPLAINED.

BY

W. BOHNE,
OPTICIAN.

WITH ILLUSTRATIONS.

PUBLISHED BY THE AUTHOR,
(With A. B. GRISWOLD & CO.)
No. 119 CANAL STREET, NEW ORLEANS, LA.
1888.

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TO

H. GINDER, Esq.,

MEMBER OF THE MERCANTILE FIRM OF

A. B. Griswold & Co.,

OF NEW ORLEANS,

As a feeble expression of my great esteem for his sterling integrity, a grateful acknowledgment of his encouragement in furthering my present project, and as a token of my sincere friendship, this little work is

Respectfully Dedicated

By the Author.

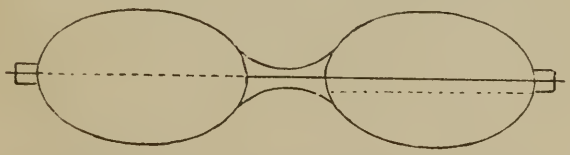
ABBREVIATIONS.

D	=	diopter.
ax	=	axis.
C or cyl.	=	cylindrical.
cc	=	concave.
cm	=	centimeter.
cx	=	convex.
m	=	meter.
mm	=	millimeter.
S or sph.	=	spherical.
—	=	concave.
+	=	convex.
⌒	=	combined with.
°	=	degree.
′	=	foot.
″	=	inch.
‴	=	line.

ERRATA.

Page 19, line 20, for — 40 D read — 40″ or 1 D.

Page 37, figure *a b* should be replaced by the following, which shows the incorrect setting of one of the prisms.



Page 104, line 16, for Spectacle-glasses read Spectacle-lenses.

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PREFACE.

When I first devoted myself to the pursuit of an optician by selling spectacles and fitting glasses, I found myself confronted by many difficulties. I looked around for an instructor in the shape of a practical "Hand-Book," such as I present here to young opticians. I vainly searched in book-stores and in catalogues; I asked oculists and other authorities for a book written especially for opticians. But all I found were not such as I was so much in need of. I knew the theoretical part of our trade from former studies, as well, I believe, as it was known at that time; but as to the practical part of the trade I had embraced, I never could find any guide up to the present day. I may say, therefore, that my book fills a want keenly felt by all opticians.

There is still fresh in my memory the great mortification I once suffered from my ignorance of the *optic centre* in spectacle lenses. An elderly lady wanted me to exchange the lenses in her spectacles for stronger ones, and we soon found the right number. The lady was delighted with them, and took a seat while I was busily engaged in cutting and grinding them. At that time I did not use any pattern or marker. I commenced to chip the lenses at random, as near the shape of the frame as possible. Unluckily one lens broke out too close to the centre; but as the remainder of the lens was large enough to fill the frame, I finished it off, and handed the spectacles to the lady, expecting the same approval of my work as she had before bestowed on the good selection of the lenses. She put the spectacles on, and looked at some print, but

soon took them off, wiped her eyes and tried again. She moved the paper and turned her head, while I was waiting impatiently for this approval. But imagine my surprise when she asked me if they were the same glasses she had tried before, and if I had not made a mistake. To satisfy myself, I remeasured them, and told her that they were all right. She insisted on having her old glasses replaced, and left my store with the remark that I could not fit her eyes. I would have paid, at that moment, one hundred dollars to anyone who had cleared up this mystery to me, and by showing me where I had failed, had saved me from another similar humiliation. From that time I took a memorandum of everything I thought of any value to our trade, and I have made use in this book of items written twenty-five years ago.

My object is to instruct the rising generation of our trade, and elevate them to the position of the great progress our business has made within the last quarter century. I regard my readers as my apprentices *at the workbench and behind the counter*. If this work should accidentally fall into the hands of fellow-craftsmen of superior skill and experience, I am certain that even these fortunate men will find something in it which will fully repay them for their outlay. I am well aware that it is not as complete as it ought to be, because every chapter is composed and written as *something new*. There is nothing previously published about these subjects, as far as I know; and my little book may be the pioneer to open the road for other more able writers. All other trades have their literature; every other art has a *handbook* of the secrets peculiar to its business; but the optical trade, as regards the mechanical part of it, has none whatever. Books written for our instruction treat only of the theoretical part, but none tell us how to set a lens, how to find the optical centre, etc. Their writers were

not practical workmen; they had to limit their instructions to the selection of glasses for certain special cases. This theoretical part I have purposely declined to copy from other authors, and to enlarge and embellish my book with strange feathers. That which I offer is the result of a life-long experience, and of numerous investigations; and I hope it will be received by the trade with favor and forbearance. Workmen who find any error, or who know better methods of accomplishing anything in an improved style, are cordially invited to communicate it to the author, who will not fail to take notice of it, and acknowledge his obligation in a future edition. As I desire to make this little work as useful as possible, I sincerely request every one, who can offer any suggestion for its improvement, to give me the benefit of his experience. It is time for the optical trade to arouse from the lethargy with which we have carried on our business. Let us look at the immense progress the *oculists* have lately made! If we do not keep step with them, and are not able to fill their orders, who is to blame?

Let us remove that curse of all progress—the keeping of our secrets and little tricks to ourselves. Let every workman withdraw the restriction upon fellow-laborers from entering his shop, in order to prevent them from profiting by his skill. It is not knacks and tricks that constitute the value of a workman; but skill, judgment and quick perception must be the only distinction between the conscientious and careless, the good and bad workmen. This is the proper way to elevate our trade to a commanding position, based upon skill and merits, that we may no longer be confounded with street-fakirs and mere spectacle-vendors.

The contents of this book furnish to any young man a solid foundation of what he ought to know, and enable him to master all difficulties he may encounter in the pur-

suit of his occupation. It would be folly for anyone not to try and improve on what he finds here; the brightest medical student will be but a poor practitioner even after ten years, unless by constant study he keeps at the head of his profession. This is the age of electricity, and electricity travels fast. There is no telling what demand will be laid on the ability of the optician in the immediate future. But as long as he understands thoroughly the fundamental laws of his trade, there is nothing that can puzzle him more than a moment to master it completely. A mechanic who skillfully handles his hammer, his file, drill and turning-lathe, is not embarrassed by any order different from his routine-work. In a short time he feels himself at home, performing his work as easily as if he had done nothing else all his life-time. This is the great advantage of a competent workman. Like the tools that he handles he says nothing, but he can be relied upon for successful work. He is totally different from those arrogant members of the trade who pretend to be brimful of secrets, but who are poor in execution.

One of the fundamental points of our trade is a clear conception of the *optical centre* of a lens, as explained in Chapter V; and no optician can lay claim to his title if he is not fully familiar with it. If this book should fall into the hands of the foremen of manufactories, I hope it may enlighten them for the benefit of the spectacle-wearing public; because, on an average, ten per cent. of the lenses, even of the better classes of goods, are misfits. This greatly annoys all conscientious opticians, and inflicts serious injury upon those who have the misfortune to purchase such lenses, and to wear them without correction.

Another important and more difficult point is explained in Chapter VII, which treats of "Compound lenses, their measurement and correct setting." Since the oculists

have succeeded in correcting those irregularities of the cornea, called astigmatism, by means of cyl. lenses, and have become able to determine its degree by paralyzing the muscle of accommodation with atropia, we have been compelled to combine cyl. lenses with cx and cc lenses. This was done, at first, simply by gluing two lenses together with Canadian balsam. But opticians soon learned to grind both corrections on one lens, and are now able to add even a prism to these spherical and cylindrical combinations. The oculists were indeed well sustained by the skill of our trade: and I think the honor of this achievement should be equally divided between the oculists and opticians; as it is customary, when we admire the solid structure of a handsome edifice, to give credit to both the architect and the builder.—This chapter explains in a manner easily understood, all the difficulties connected with this most delicate correction in the shape of spectacles; a subject which is yet, for many opticians, the stumbling-block to their efficiency and ability. This should not be so; for often our trade is blamed *in solido* for the incapacity of individuals.

Chapter III has for its object the much abused "Pebbles," and is something altogether new. It differs from everything heretofore published; and I hope that my experiment will be repeated by opticians and scientists, in order to settle finally the vexatious question: Shall pebbles be used or not? This matter should be decided under any circumstances, and the sooner, the better. If pebbles are really injurious, they must be discarded, as has been the case with many renowned remedies and medical treatments, much favored at one time, and afterwards thrown aside as useless. My theory about pebbles may be wrong, but the test I produce in their favor is very convincing, and I am anxious to hear what their opponents have to say, and are able to prove.

The history of the "Invention and Introduction of Spectacles" is the first attempt at collecting the scanty materials about this important subject, and is far from being what its title indicates; but I hope that those of my readers who are in possession of any facts concerning this matter, will kindly communicate them to me for future use.

The articles in the Appendix do not belong strictly to the tenor of my book; but they contain some philosophical truths referring to the eyes in general, and may be of practical value to my readers, especially the article giving instructions for the relief of injured eyes.

The list of *Contents* shows that every essential part of our trade has been discussed as *far as spectacles are concerned*. It may be urged as an objection against the completeness of this work, that I omitted to notice the modern machines now used in the larger establishments and manufactories. This is no oversight or ignorance on my part. I have not labored for the instruction of manufacturers, but for the benefit of the many thousands of small dealers who buy their spectacles ready-made, and provide themselves for exceptional cases with frames and lenses, as they are offered by wholesale houses. These retailing opticians and jewelers are almost helpless in many respects without such a guide; and to enable them to give satisfaction to their customers, as well as to promote their interest in this particular branch of business, by removing for them insurmountable difficulties, I have presented the results of my experience in a practice of thirty years as a jobbing optician.

May this little work meet with a kind reception from the trade, and a mild review from the critics.

New Orleans, Nov. 16, 1887.

WM. BOHNE, Optician.

CHAPTER I.

Introductory Remarks — Diopter or Dioptric — Inch and Metric Systems.

Glass is the most transparent of all the solid substances produced by man, and is a good imitation of that valuable product of nature, rock-crystal or "pebbles," which are but pure crystallized quartz. The Latin name for quartz is *silex*, also *silica* and *silicic acid*, according to certain distinctions mineralogists make. It is composed of fifty per cent. of oxygen with about an equal proportion of its base, called *silicium*, which is supposed to be a metal, like potassium and sodium; but chemists cannot yet reduce it to its metallic state. Fifty years ago they extracted the base of *clay*, in the form of that extremely light metal, *aluminium*; but the metal *silicium* is yet waiting for its discoverer.*

To manufacture *glass*, we must take quartz or sand (the latter is only powdered or crushed silex), and melt it together with either potash or soda, with the addition of lime, borax, lead and other ingredients which facilitate its fusion. Quartz or sand by itself will never melt; it is perfectly infusible; but it acquires the property of

*After having written the above, I ascertained that a commencement in this direction has been already made in electroplating with Silicium, obtained directly from silica by means of hydrofluoric and hydrochloric acids. The metal Silicium is then invisibly suspended in the solution in which the article to be plated is immersed, and is set free by the action of a galvanic current. In this way we obtain a thin film which is nevertheless the real metallic base of silica.

When we consider how tedious were the first experiments with Aluminium, and in what quantity and with what facility this metal is now produced, we may also expect to see Silicium introduced sooner or later into the market, as a new metal for ornamental or industrial purposes.

fusibility in a greater or lesser degree according to the quantity of the above metallic oxides with which it is mixed before undergoing the melting process.

In reference to spectacle-lenses we have to deal either with pebbles, flint-glass or crown-glass, whose different qualities will be discussed in the next chapter. The lenses mostly used are ground spherical, and are either convex or concave. Cx lenses collect the greatest portion of the rays falling on their surface at one common point called the "focus;" concave lenses, on the contrary, disperse or scatter the rays, and have only a negative focus. Cx lenses are always thicker in the middle than at the edges, and are of different form or shape, either double or bi-cx, plano-cx or periscopic convex.* Concave lenses are thinner in the middle than at the outside, and are also double or bi-concave, plano-cc and periscopic-cc. The advantage of one form over the other is yet an open question. I, for my part, find that the stronger numbers of periscopic lenses are extremely unpleasant to the eye, especially when they are used for cataracts. All that is claimed for their superiority may be justified in the weaker numbers from 1 to 4 diopters.

Diopter, *Dioptry* or *Dioptric?* Which is right and should be used? The latter word is derived from "dioptrique," applied by the French to optical measurements, as a substitute for the term *meter*, which, though it denotes measure in general, has no particular application to optical measurement. On the other hand, the great objection to "dioptrique" is that it denotes no measure whatsoever. Both in its derivation and its use it refers to the refraction of light, but not to any kind of measurement. It is not a new word, but has been assigned a new meaning, not in accordance with the logical rules of language. It is not a noun, but an adjective, in its form and meaning. The word *dioptry* would, from its termination,

* For explanatory Cuts see Appendix F.

present a better claim to be used for our purpose; thus we translate "replique" into *reply;* but as most nouns relating to measure end in "ter," from meter, thermometer, barometer, up to a geometer, I think it best to adopt that spelling for it which I have used throughout this book.

This word *diopter* denotes also a geometrical instrument used for leveling purposes. The original word is taken from the Greek *dioptriços* (dia=through, optomai=to see), meaning something which assists vision by means of the refraction of light. This assisting medium is always a dioptric lens, or a combination of lenses, from the telescope down to a pair of spectacles.

The substitution of this word for meter has been adopted by oculists and all first-class opticians since 1875, in the interest of the legitimate trade, partly to prevent bunglers from filling orders of oculists, and from taking advantage of the fruits of science without troubling themselves to study and become experts in the optical trade, and also to adopt a uniform measurement instead of the old inch measure, which differs according to its length in different countries.

Spectacle-lenses are never mathematically correct, like those of scientific instruments, because nobody would pay the price for them, and, in fact, nobody would detect a great difference or be much benefitted by them. Just see how most people put on their glasses. How carelessly! How crooked! They have no more use for such perfect lenses than an Indian has for classic music.

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When the lenses are well centred, the focus will be a sharp point in sunlight; otherwise it will form a circle, an ellipse, or only an irregular patch of light. The very common spectacles are always badly centred, and never correctly measured, and should not be sold by any conscientious optician. If people are willing to

injure their eyesight for the sake of a few dimes, let them do so; but you should rather lose the sale of an article than be parties to such reprehensible dealings. Druggists are forbidden to sell poison; why does not the law prevent the traffic in "eye-killers"?

The first qualification of an optician is his ability to *measure* lenses. The introduction of a new measure only confuses people, so long as they have not forgotten the old style of measuring. We experience the same difficulty with the metric system. A diopter has, in American measure, 39.37", and in Paris, 37"; only the inches are different, not the meter. To find the difference between an American and a French foot in lines, multiply the number of lines in one foot (144"') by 37, and divide the product by 39.37. The quotient will be 135.3"', which is the length of an American foot in French lines. The French foot of 144"' is therefore 8.7"' longer than the American.*

This explains why imported lenses never correspond with our numbers, and have to be remeasured. When we order +20, we find them generally to be +22; and it is only by keeping in stock the half numbers, as $5\frac{1}{2}$, $6\frac{1}{2}$, etc., that we are able to fill correctly the orders of oculists. This trouble is overcome by the *metric system*, as a meter is independent of the special measurements of the different countries.

Let us now turn our attention to the practical method of measuring lenses; and first, by the *inch system*. If you have in your store or workshop a suitable place to fasten permanently a ruler of 40" in length, horizontally, with a white card attached at zero, and counting from there in the direction of a conspicuous object, for instance a window or a railing, it is easy to find the

* The French inch is 27.07 m m. the American only 25.3 m m.

focus by moving the lens to and fro till you have a well defined picture of the window, etc., on the card. This figure is always reversed, the reason for which will be explained in another chapter. As soon as the figure shows clearest, you count on the ruler the number of inches, which will be also the number of the lens. There is no difficulty in measuring, in this way, convex lenses up to 30″; beyond that, it requires greater care, and some practice to distinguish the faint picture on the card, especially in cloudy weather. The surest way to measure weaker lenses than + 30, is to place two together and measure them jointly. Two lenses of + 48, will give + 24, and one lens separate will be again +48, or half the strength of + 24. But if we have two lenses apparently of the same strength, which are actually + 60 and + 72, how can we ascertain that they are of different strength? Our ruler will be useless to us, even if we lengthened it sufficiently. Here we have to fall back on our own eyes, and let them render judgment. Take for instance a folding foot-rule of 2′ and open it enough to just introduce a pin-head between the open ends. You will hardly think that this little opening has much effect on the parallelism of the two lines. But now place this foot-rule so that the continuation of one branch strikes a point several hundred feet away from you; then, without moving the ruler, follow with your eye the other line, and you will see what effect this little opening has. You will understand by this, that you have to compare such weak lenses by looking at remote objects. If there is convenient a roof of a house one or more hundred feet away from you, take the two lenses, + 60 and + 72, one in each hand: hold them edgewise together, and look through them at arm's length at the roof; move one or the other lens up or down till you see the lower line of the roof straight through both glasses.

Now look, without moving the lenses, at the upper line, and you will find that it is higher in one lens, and this is of course the stronger one, as it is of greater magnifying power.

There is a certain method to measure cc lenses; but I, for my part, have practiced it only as an experiment. When the sun shines upon a cc lens, we do not see a clear focus, but only a shadow of a certain dimension. The more we move the lens toward the sun the larger will be the shadow; and if we continue to move it till the shadow is just double the size of the lens, this distance, in inches, is its strength. This method however is of no practical value. As we are able to measure cx lenses very accurately, we can use them as a standard measure for cc lenses by neutralizing the cc lens with its corresponding cx lens. If you have any cc lens, of which you do not know the number, pass before it different numbers of cx lenses till you come to that lens which makes them both together appear plane, and the number of the cx lens is then the number of the concave one: + 7 and —7 is 0 or plane.

The *metric system* is based on the length of the meter which is very nearly 40 inches. The great advantage of this new measurement is that it enables us to make calculations and combinations of lenses without the least trouble. The old way of calculating combinations in inches is more or less difficult; we have to turn the numbers of glasses into fractions, and instead of + 40 we say $+\frac{1}{40}$; instead of + 20, $+\frac{1}{20}$, etc. Suppose somebody is wearing $+\frac{1}{27}$, but cannot see well, and we add another lens $+\frac{1}{40}$, by which combination he sees perfectly; then we have to make the calculation in this way:

$$\begin{array}{l} +\frac{1}{40} \\ +\frac{1}{27} \end{array} \left| \begin{array}{c} \frac{40\,.\,27}{27+40} = 67 \\ 40 \end{array} \right| 1080 \Big| = +16 \text{ inches.}$$

Not every dealer is sufficiently familiar with his

arithmetic to be always sure of a correct result; and it will be well therefore to present an easier method by which all possible combinations may be made by simple addition or subtraction. This can only be done in the metric system.

One meter or a *diopter* is exactly 39.37 of our inches, so 2 diopters are the half of it=19.68″. Some catalogues of importers and manufacturers of spectacles give all the fractions arising from a careful calculation of diopters into inches, but they are of no practical value whatsoever. If we take the meter at 40 inches and make our calculation accordingly, we will be always near enough for all practical purposes. To illustrate the easy way of making the above calculation, look only at the annexed table, giving the most rational comparison of diopters with American inches. You find there that + 27″ are 1.50 diopters, and that 40″ is one diopter; add both together and you have + 2.50 D or + 16″. If anybody is wearing these spectacles (+16″), and you find that they are too strong, but are corrected by adding —40 D, then you have to subtract 1 D from 2.50 D, leaving + 1.50 D, or + 27 inches.

To give an illustration of the difficulty in making correct calculations by the inch system, let us take for instance an achromatic lens, composed of a crown-glass of + 4⅓ inches and a flint glass of —7⅔ inches. These two lenses combined give one lens of +10; but by the ordinary way of adding the two sums, we may get a lens of —10 in our calculation. To solve this problem correctly we have to make use of one of the first algebraical rules of addition, which reads: "When the signs are unlike, prefix the difference of the two sums with the sign of the greater part." In ordinary calculation 7⅔ is the greater sum; but in optics we know that 4⅓ is nearly twice as great or strong as 7⅔, and in adding the two

sums we have to prefix therefore the answer by the sign +, as the practical test shows it to be correct.

By means of the metric system we have not the least trouble in finding the value of those two lenses combined:

$+ 4\frac{1}{3}$ equals $+ 9$ Diopters,
$- 7\frac{2}{3}$ " $- 5$ "

added together gives $+ 4$ " equal to $+ 10$.

The annexed table will answer for all practical purposes.

Diopter,	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50
Inches:	160	80	54	40	32	27	23	20	18	16
Diopter:	2.75	3.00	3.25	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7
Inches:	$14\frac{1}{2}$	13	12	11	10	9	8	7	$6\frac{1}{2}$	6	$5\frac{1}{2}$
Diopter:	8	9	10	11	12	13	14	16	18	20
Inches:	5	$4\frac{1}{2}$	4	$3\frac{1}{2}$	$3\frac{1}{4}$	3	$2\frac{3}{4}$	$2\frac{1}{2}$	$2\frac{1}{4}$	2

Between these numbers there are only 27, 23 and $14\frac{1}{2}$ not common to our inch system, and they may be changed into 26, 22 and 14; all others are represented by the old inch measure. I do not recommend that the orders of an oculist be filled in an inaccurate way in order to dispose of the lenses we have on hand. It requires only a small outlay to obtain at least the above numbers in diopters. It is unquestionably the best policy for an optician to complete his stock by degrees with all numbers of the metric system; but in cases of necessity, we will be near enough if we substitute one for another, according to the above table.

CHAPTER II.

Different Qualities of Lenses.

Many opticians are mistaken about the hardness of flint-glass and crown-glass. The general opinion that the former is the hardest, obtains even among noted writers. Dr. Donders, for instance, says: "Flint-glass and rock-crystal are harder than crown-glass." I do not understand how this error could slip into so many medical books, as the simple test of scratching the one with the other will show at once that flint-glass is softer than crown-glass. Dr. Donders is not so much to be blamed for this incorrect statement as those who reproduced his error without any further investigation. I read lately in a valuable geographical work of Dr. H. Berghaus, that *Washington* served his country twelve years as President. I do not think less of Dr. B. for making this erroneous statement, but I censure every writer who quotes him as an authority on this subject.

We find another error in regard to *Pebbles* repeated in many books written by thoughtless compilers, because one copies it from the other without examining the facts; and as the first writer was mistaken, all the rest labor equally under the same gross misrepresentation. I will correct, in the next chapter, those errors which have, for years, caused an open contest between oculists and opticians. The oculists based their objections on books of high authority, and the opticians yielded to their arguments from sheer want of correct information. I warmly urge both to devote some of their leisure to investigate this question thoroughly, and settle it definitely.

Let us first see what material is necessary for the manufacture of glass. Glass cannot be made without quartz, which must be crushed and powdered to sand before it can be melted. To avoid this labor, the manufacturer prefers to take at once sand of a clear grain. The mixture of sand and potash or soda melted together, gives the so-called *water-glass*, which is soluble in hot water, and is readily affected by acids; but to prevent this, lime is added. These three ingredients, *sand*, *potash or soda*, and *lime* or another metallic oxide, are absolutely necessary for glass-making. To facilitate the melting process, and also to produce different kinds of glass, there is added, what is called *flux:*

1. *Baryta*, which renders it more easy of fusion.

2. *Manganese*, termed "glass-makers soap," which neutralizes the greenish tint produced by iron.

3. *Borax*, must be used with great caution, as an excess causes exfoliation of the glass.

4. *Lead* (in the form of red lead or litharge), removes impurities, and is the distinguishing ingredient in crystal or flint-glass.

5. *Arsenic*, promotes the decomposition of other ingredients, and tends to dissipate carbonaceous impurities not otherwise disposed of, but is then volatilized.

6. *Alumine* and *Iron* are seldom present, and very undesirable in the finer qualities.

There are four varieties of glass manufactured, besides the water-glass:

I. *Flint-glass*, also called *Crystal*, *Strass* or *Paste*. This is a very pure and beautiful kind of glass, of great density and high refractive power. It consists of

42.5	parts of	silica.
43.5	"	" oxide of lead.
11.7	"	" potash.
1.8	"	" alumine.
.5	"	" chalk or lime.
100.		

It has the highest degree of lustre, but is soft and easily scratched. The specific gravity is 3.7, while that of crown-glass is 2.7, and of rock crystal only 2.6. Many opticians may have confounded density with hardness, and have made the same mistake as they would, if they maintained that dense and compact chalk was harder than light and porous pumice stone, although the hardness of the first is 1, and of the other, 7. Density is the opposite of rarity, but not of softness.

II. *Window Glass, English Crown and Plate Glass.* This is made of silica, soda and lime, and is used extensively for spectacles of the second quality. It is composed, when used for optical purposes, of:

White sand	120	parts.
Carbonate of potash,	35	"
Carbonate of soda	20	"
Chalk	20	"
Arsenic	1	"
	196	"

There are 55 parts of potash and soda in 196, which is equal to 28 %, against nearly 12 % in flint-glass.

III. *Bohemian or Crystal-Glass*, made of silica, potash and lime.

IV. *Bottle Glass*, made of silica, soda, lime, alumine

and iron. This glass is the hardest, but the most impure, and has always a greenish tinge.

You see from this list that the dearer potash is used for the better qualities of glass, and the cheaper soda for the inferior kinds. If either of them is employed too freely, it spoils the glass. You have perhaps made the observation, after having carefully cleaned a mirror or window, that soon there was a scum again covering the just brightened surfaces. A repeated rubbing readily removed it only to re-appear as soon as you ceased your efforts. The excess of potash or soda in the glass attracts the moisture of the air, and baffles your exertions. Don't laugh any more at people complaining that they can never clean their spectacles; the lenses may be manufactured of such defective glass.

There is another serious evil attending the excess of these alkalies in glass, when they gradually oxidize by the action of the atmosphere, causing the appearance of rainbow colors. But when in the length of time the potash and soda are more and more absorbed from the surface, there is left only a thin film of oxidized silica of a milky appearance, such as you find on spoiled lenses, especially on watch-glasses, which are mostly made of glass containing much soda. Such lenses cannot be cleaned by any acids or by any amount of rubbing, but only by being reground and repolished in the factory, which does not pay expenses.

I think it proper here to direct your attention to the many so-called *inventions* of certain "smart" and unscrupulous impostors, introducing their wonderful discoveries as something of the greatest importance, i. e., for their own pockets, not for the public. The only invention they have really made, is the *high sounding name* which they first flourish ostentatiously before the eyes of the amazed public. Then they wait eagerly for the rush

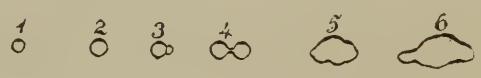
of deluded buyers, as the picadores in the arena wait for the headlong advance of the bull, enraged by the waving of red cloth. Such names as *Perfected*, *Improved*, *Brilliant*, *Arundel*, *Diamond*, *Medicated*, *Diamanta*, *etc.*, are still fresh in our memories, and the list will increase as long as there are dupes enough living to make such a humbug pay.

It is very important to every optician to be well informed about the *different qualities of lenses;* he should be able to determine their various grades as readily as a jeweler is able to ascertain the karats of goods he is buying. Before we speak of the proper test, let me correct a common mistake in regard to the manufacturing of lenses. They are not always ground from square flat pieces of glass, but are now mostly cast or moulded into the shape they have when finished. Only the better qualities receive, afterwards, their finishing touch by the grinder and polisher, while those lenses with somewhat even surfaces, are only superficially polished, and are then ready to be used for cheap spectacles. Lenses of the *first quality* always contain more or less lead, the larger its quantity (to almost half its volume), the finer its lustre and beautiful sparkling. This kind is known to the trade as *extra white* flint-glass, and cannot be distinguished from pebbles by simply comparing them together by look. It is principally used for opera and spy-glasses and other optical instruments. The best method of comparing different lenses is to place them horizontally or flat between your fingers, and by holding the hand towards the light, you can see then in the narrow open spaces between your dark fingers the different degrees of the color of these lenses better than by placing them on white paper. But most lenses sold for first quality are not the *extra white*, and cannot stand comparison with pebbles; the simple hand-test shows a grayish tinge when compared with them.

Lenses of the *second quality* contain no lead, have a greenish tinge when examined edgewise, but take a high polish, are harder than flint-glass, and are decidedly preferable for cataract lenses.

The *third quality* is not always made of poorer glass, because many lenses from the better qualities are selected to be used as they were cast. We find therefore among them very often white lenses, but they are never ground, and seldom polished. Their cheapness is due more to saved labor than to less costly material.—I could extend the list of the different qualities to fourth and fifth grades, when I look around among the stock in trade of our street-corner opticians, but I hope none of my readers will be caught selling such trash. It is true, the eye can stand a great deal of abuse, but the wearer of such spectacles will at last share the fate of a spendthrift: the one loses his fortune, the other, his more precious sight.

A good lens, no matter if made of flint or crown-glass, is always well ground, polished and correctly centred, without flaws and streaks. "Correctly centred" means that the centre of one side is exactly opposite the centre of the other side, the continuation of these centres forming a right angle with the surface of the lens, and giving a well-pointed focus in sunlight.



No. 1 is perfeetly centred, No. 2 not so perfectly, No. 3 and 4 are each of the shape of focus No. 2 when held slightly oblique; the centre of each side of the lens produces its own focus. Nos. 5 and 6 show only irregular patches of light, very often seen by cast lenses.

To detect other imperfections we have to hold the lens at an angle of 35 ° in good light. The reflected light will show

the smallest bubble or scratch in or upon the glass. Another and better method is to hold the lens before the eye, and look through it at a window. (This test refers only to ex lenses.) You will see the object behind it only dimly, and in lengthening the distance gradually, it will appear dimmer, till at once you see nothing but the glary lens,—it is just in its focal distance. If you remove the lens beyond this point, the object is then clearly seen but reversed, because the rays have crossed in the focus; the upper rays are now the lower ones, and vice versa. This point where you see nothing *behind* the lens, is the most proper for detecting all imperfections in it; you only direct it to some light colored object, or towards the sky.

This test is also the best to detect the defective crystallization in *pebbles*.

CHAPTER III.

Pebbles, *their Merits and Defects.*

For more than a hundred years, after cotton began to be cultivated in America, its seeds were considered worthless, and on every plantation large heaps of this contemned stuff accumulated in the course of time, which the planter would have gladly given for nothing, if anybody had been kind enough to cart it away. To-day, the seed yields more profit to him than the cotton. Pebbles met with the same treatment. Neither the builders had any use for them, nor street-pavers; only mineralogists noticed them, and occasionally collected some specimens as cabinet-pieces. A few manufacturers of glass also used them for making an extra quality of flint-glass, but millions of tons of this precious substance were left unnoticed by those who are now eagerly searching for it. Since 1783, when Abbe Rochon, the first writer on pebbles, gave an unfavorable account of them, and condemned them as useless for spectacle lenses, all writers on the subject are against them. Listen to what the Doctors say:

"The only practical advantage of pebbles over glass is, that they enable us with all honesty to gratify persons who do not know what they want, but simply wish to pay more than the usual price, or more than their friends did for their spectacles."

Another says:

"Rock-crystal, or Brazilian quartz, is also used, and is commonly known as *pebbles*. It has no advantage over glass, except in hardness; in fact, the opticians find it

difficult or impossible to distinguish between them without a polariscope or a file. Many people, however, are not satisfied unless they have pebbles, or think they have them, for glass is very often sold instead." This physician forgets that jewelers are also compelled to use touchstone and acid to test gold. Is gold therefore less valuable?

I frequently tried to find some definite information about pebbles; but being unable to discover any book or pamphlet treating of this subject, either here or in Europe, I concluded to search for myself, and ascertain if there was anything in it to repay the labor. Only a superficial glance at them revealed their extreme transparency, and plainly showed that few spectacle-lenses possessed that brilliancy which characterizes these much abused pebbles. I asked myself the question: Why shall we abandon the natural, pure glass for an artificial substitute; the reality, for an *imitation?*

The genuine article has two striking advantages over glass which cannot be denied: its *brilliancy* and its *hardness*. The principal objection made against the use of pebbles is their *double refraction;* but this is seen only in thick pieces, when we look over their slightly inclined surfaces. Objects reflected from polished planes of massive pieces appear double; but this is not the case with thinner plates, like spectacle lenses.* Since, therefore, double refraction affects vision only in thick pieces and

* "The double refraction of rock-crystals renders them useless for optical purposes, and especially for the manufacture of spectacle-lenses, and although the images do not appear doubled across such lenses in consequence of their thinness, and the manner in which they are used, it is nevertheless true that double refraction exists, and that it can cause considerable trouble to vision by weakening the retina, and producing fatigue of the accommodation or even a kind of amblyopy."—Manuel de l'Etudiant Oculiste, par Arthur Chevalier.

not in thin ones, what reason have opponents to prejudice the public against their use? Why not raise their voices likewise against the use of small quantities of arsenic, belladonna and other poisons? for it is well-known that large doses of them have deadly effects. On the contrary, they, as well as the most cautious and conscientious physicians, daily prescribe small doses of these poisons, with successful results.

This is the only serious objection ever made against pebbles, and I would think it too insignificant in comparison with their other high qualities, which give them a prominent place among all their competitors for spectacle lenses, to waste another word in their defence, if it were not my object here to settle the dispute definitely, and furnish all the points necessary to justify my honest opinion about them. The main object of my investigation was, therefore, to ascertain, if the eyes were sooner fatigued with pebbles than with glasses. I directed my attention especially to the general cause of our getting weary, and I found that it was the effect of *heat* relaxing the muscles and producing the sensation of fatigue. People say: "My eyes burn," meaning that they are fatigued. In fact, as soon as any part of our body is overheated, it feels tired. A long walk produces an increased flow of blood into our limbs and feet, we feel fatigued, and find relief in cooling them. This also explains why we grow tired sooner in summer than in winter, though doing the same amount of work.

The proper way, therefore, to reach a positive result, is to measure the amount of caloric rays transmitted through pebbles and glasses respectively, and to find the difference in favor of one or the other. This test I first made sixteen years ago: and I have repeated it before writing this article. I give here a brief description of the manner in which it is done. We can measure the different

degrees of heat only by means of thermometers; and in order to make this test simultaneously with different lenses, I selected six thermometers that worked accurately together; then I took an *axis pebble*, a *non-axis pebble*, a *flint-glass*, a *crown-glass*, a *light smoked* and an *Arundel lens*, all of + 8. I made a slender frame-work to hold the lenses and the thermometers; then removing the thermometers from their casings, I placed them, one each, in the focuses of the lenses. To guard against any inequality in this test, I took a straight piece of sheet-iron, and had six holes punched out, all of the size of a silver quarter dollar, and fastened the lenses behind each hole so that the optical centre of the glass was in the centre of the hole.

I took altogether thirty-two observations, with the following result:

The	smoked lens showed	78°	on the	average.
"	crown-glass, "	81°	"	"
"	non-axis pebble "	81½°	"	"
"	axis-pebble "	82°	"	"
"	flint-glass "	83°	"	"
"	Arundel lens "	84°	"	"

The lesson we may draw from these observations is that we should dispense with flint-glass and all colored lenses, except smoked. Crown-glass and pebbles are then left as the only rivals for spectacle-lenses.

Crown-glass is not always manufactured of sufficient clearness to suit optical purposes; most of it contains iron, which gives it a greenish color; then, too, the small proportion of potash in it prevents the sand from being melted into a perfectly pellucid mass. The best formula for making crown-glass for spectacle lenses we find in the preceding chapter. This glass has an index of re-

fraction of 1.538, and an index of dispersion of 0.037, while the best flint-glass has an index of refraction of 1.633, and of dispersion, 0.049. When we take into consideration that the greater the index of refraction of a lens, the more dazzling it is to the eye, and the greater the index of dispersion, the more annoying and fatiguing, we cannot hesitate in making our choice. Besides, crown-glass is the hardest of all glasses used for spectacles, and is at the same time much cheaper than flint-glass.

In reference to pebbles, we have to take notice of their greater index of refraction (1.548) which accounts for the higher stand of the thermometer in the trial-test. The difference in the refraction of both is but very small, and is fully balanced by the lower index of dispersion, which is only 0.026 in pebbles. The difference of the thermometer between axis and non-axis pebbles puzzled me at first considerably; but I think it can be fully explained by the presence of the prismatic colors in axis pebbles. The red ray is very predominant in such lenses, and as *red* is the caloric ray "par excellence," it explains the greater heat in comparison to non-axis pebbles. I believe this also covers the case in regard to Arundel lenses, which are based altogether upon a wrong theory. When we resolve the light by a prism into its seven colors, and examine the caloric of the violet ray, we find it of much lower temperature than that of the red ray. But when we produce a *violet glass* (which is done by the addition of oxide of manganese to the other ingredients), and let the light pass through such a lens, the red ray receives of course an additional force from the somewhat reddish lens, which sends a warmer light to the eye than white glass would do. The violet ray of the spectrum is separated from the other rays, and is, therefore, cooler; but a violet *lens* cannot exclude the other six colors. It cannot by the exclusion of the other colors give the eye the benefit of

only that cool portion of the white light which is contained in the violet ray.

It now remains to decide which pebbles are preferable, the axis or the non-axis. I am not prepared to give a categorical answer to this question; but I hope that more able writers will investigate the subject and free it from the false opinions entertained upon it for so many years. Indeed, all the ignorance of thoughtless writers have not availed to rob these crystals of their hardness, nor to obscure in the least their brilliancy and clearness. All the woful insinuations about their double refraction have been unable to double even the finest test-line in spectacle lenses, or to produce that great trouble in the eyes of the wearer which was so earnestly predicted by them. Pebbles are used to-day, and will be used in future, as long as crystals can be found; but they should be tested more scientifically and repeatedly, before we can give one or the other the preference. Meanwhile I advise all opticians to introduce either of them without the least hesitation, but to dispose only of those pebbles which are faultless as to their crystallization. There are many pebbles in the market full of imperfections; they should not be used, but thrown aside.

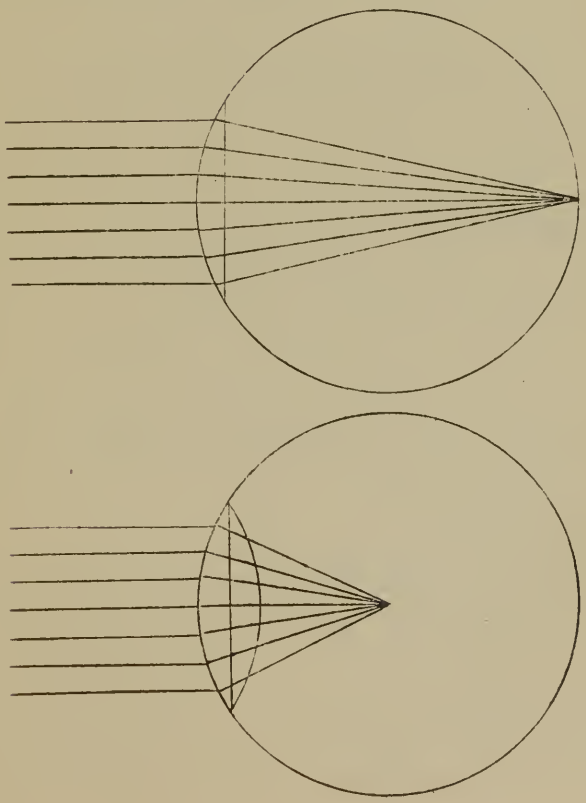
In rehearsing the merits of pebbles, we find that their hardness and clearness surpass those of any glass, and that their dispersing power is the lowest of all lenses manufactured for optical purposes. These properties eminently adapt them to cases of presbyopia and hypermetropia. But there are some defects in eyes where pebbles should never be used: near-sighted persons are not benefitted by them, nor people in need of cataract lenses, for obvious reasons. They are too glary for a near-sighted eye, and will show double refraction in thick, heavy cataract-lenses. Eyes, sensitive to light, should also abstain from using pebbles; only light smoked lenses, and

in some special cases, light blue ones can be used with satisfaction. The light tint of the blue ray has no disagreeable effect, and is almost indifferent to the feeble eye; while the increase of the other colors of the spectrum becomes injurious in the course of time.

CHAPTER IV.

Definition of Spherical, Prismatical and Cylindrical Lenses.

The word *spherical* is derived from sphere (globe or ball), and a spherical lens is the segment of a sphere. The size of the ball indicates the strength of the lens. For instance, the ball is of 2″ diameter, then the segment is of a 2 inch focus, or as we write it + 2.



The lens of the first figure is plano-convex, and its focus is at the end of the diameter: it is ex No. 2 (two inch focus). The lens of the second figure is double ex, and its focus is at the end of the radius, or at the centre; its strength is + 1 (one inch focus).

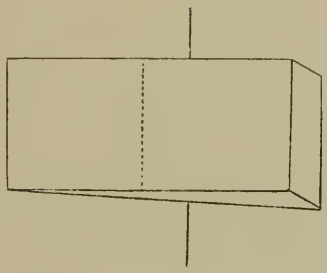
This rule is good for lenses of any other number, because the relative strength of a lens is constituted by the curve alone, and not by the thickness or thinness of the material of which it is composed. The two opposite curves can be widened by several plane glasses, put between them, without altering the focus, provided we do not alter the place or position of the lens nearest the focus, and only widen the outside half of the double lens. For instance, take two + 8 inch periscopic lenses, put the flat sides together, and measure this double lens; you then have a lens of focus + 4 inch. Hold the inside lens steady and remove the outside lens $\frac{1}{4}$ inch, and the focus is not visibly altered.

When we hold a spherical lens vertically in our left hand, and, with our right fingers, turn it around its centre, without moving our left hand, we see no change in the object we are looking at. The movement around its centre has no action on the object seen through the lens; it is the same as if the lens were held steady, and not moved at all. This should be remembered, because it is essentially different from the action of prisms and cylindrical lenses.

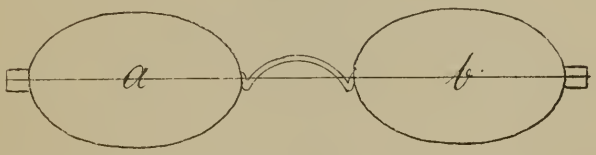
Manufacturers of optical instruments make use of this peculiarity in testing the correctness of lenses. They glue them upon a chuck of the turning lathe, and place a light at some distance in front. If the lens is well centred, the light will appear in the lens perfectly steady when the lathe is set in motion; otherwise a light circle will be visible in the lens. The larger the circle is, the more the lens is decentred; and it is only after its centre

has been correctly determined, that the workman finishes the edges. All lenses of opera-glasses, telescopes, etc., receive their finishing touch in this way on the lathe.

Prismatical lenses or Prisms are wedge-shaped pieces of glass, which break the straight line, so that it appears more to the thinner end of the glass, when we hold it horizontally over a vertical line, thus:



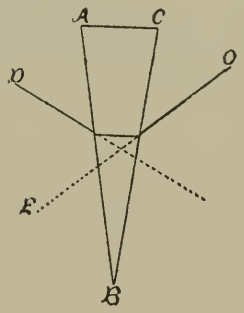
The thicker end of the prism is called the *base;* and "base in" means to place the thicker end towards the nose-piece of frame. In setting such lenses, care should be taken that a straight line is not broken in either of the lenses.



If you take two prisms of the same strength, and lay them so together that the thick part of one covers the thin part of the other, you will have a plane glass; one neutralizes the action of the other. The peculiar action of a prism consists in the displacement of an object seen through it. The object never appears where it really is; it is seen higher or lower, or more to the right or left than it should be. This is due to the different

positions in which the prism is held. Mark again the difference between a spherical lens and a prism.

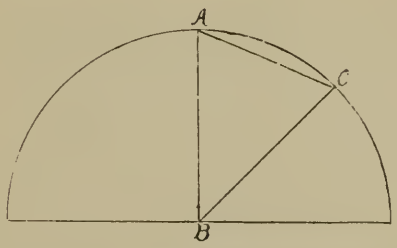
We have seen in Chapter I, the manner in which we measure spherical lenses; let us see now how we determine the strength of prisms. There is no collecting or dispersing power in a prism, as we have found in cx or cc lenses; its action is limited to the displacement of an object towards its thinner part. You can easily comprehend this action by simply comparing it with that of a cx lens. All rays falling upon a cx lens are bent in the direction of its centre or thickest part, so that they unite sooner or later in one common focus according to its focal strength. The rays which fall on the surface of a prism are also bent towards the thicker part of it, and follow this direction after they leave the other side of the prism. If our eye meet such a refracted ray of light, we do not see the object where it really is.



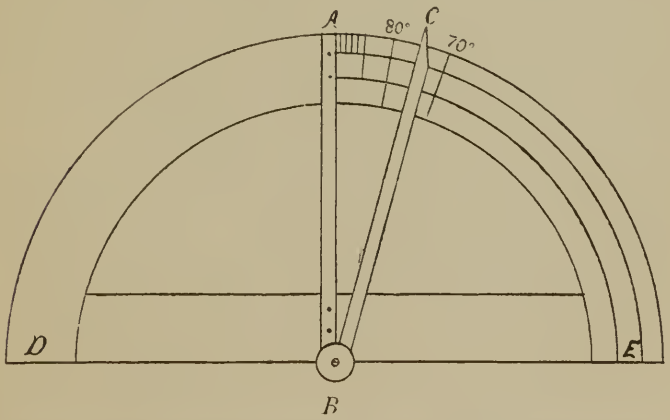
A B C is a prism, D is a ray of light falling on it, and is bent off in the direction of O. If our eye is placed at O, we see the object D, from which the light is emitted, in the direction of O E; and although the ray of light is bent towards the base of the prism, it comes apparently from the thinner part of it.

Prisms have no focal power; they cannot be measured by the inch or metrical system; but their strength is de-

termined by the angle A B C. The opening at B confers upon the prism its strength and name. We have prisms of 1°, 2°, etc. The following figure represents a prism of 45°, or the 8th part of a circle, which is, as everybody knows, divided into 360°.

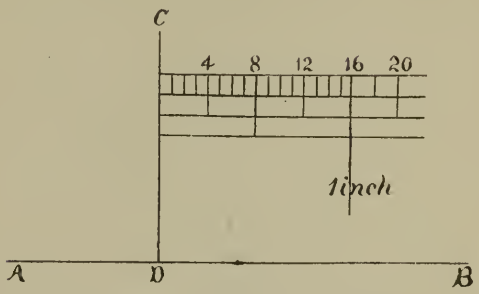


With a "trial box," containing test prisms, the strength of one lens may be determined by neutralizing it by another, as I have shown before; but to ascertain also the correctness of your test-prisms, it is necessary to construct a tool made of a *protractor*, like the following.



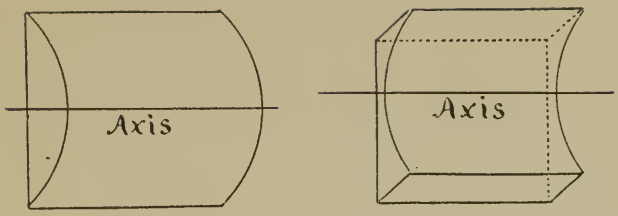
The joint B must be exactly in the centre of that semicircle D A E. That side of the rivetted or stationary bar A B which is nearest E, is precisely 90° from either D or E. The arm B C is movable, and indicates the num-

bers of degrees of a prism placed in the opening A B C. I present also another easy way of testing prisms by the use of a simple ruler.



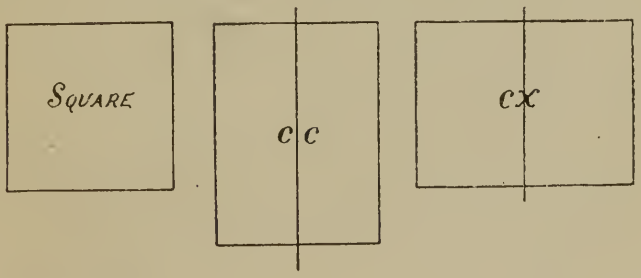
Take a ruler of 12″, American measure; cut a notch in the middle of its edge (at 6 inches) large enough for the reception of the base of the prism. Place one end of the ruler on the line A B, and the other on the cheek-bone, just below your eye; lay the base of the prism in the notch, so that the line A B is not broken in the prism; then see how far towards the right the line C D is displaced, and you will find that each degree represents 1/16 of an inch; a prism of 16° displaces the line C D, therefore, exactly one inch.

Cylindrical lenses are ground and finished with a cylinder, instead of the segment of a ball used, as we have seen before, in grinding spherical lenses. If the outside of a cylinder is employed, the lens will be concave-cylindrical; and when the concave side of a section of the hollow cylinder is used, the lens will be convex-cylindrical. The only difference in finishing either a spherical or cylindrical lens, say of 5 inch focus, consists in the first case that the grinder has to take a segment of a ball of 5″ diameter, but for a cyl. lens of the same denomination he has to take a cylinder of $2\frac{1}{2}$″ diameter, or double the strength, as the number of the lens he wants to grind, indicates.



The axis of such a lens passes along the highest or lowest ridge of it, and is easily determined by moving the lens up and down, and finding by its gradual turning that line where there is no action at all. So long as the object seen through the lens, moves with the motion of the lens, the axis is not yet found.

Cylindrical glasses have quite a different axis from the spherical, which possess, as will be seen in the next chapter, a common centre, from which the optical lines radiate in all directions of the compass, while there is only one optical line or axis in a cyl. glass. Objects seen through this line are either lengthened or shortened apparently, which is best demonstrated by looking at a square.



A cx cyl. lens with axis vertical will lengthen the horizontal sides, producing a horizontal parallelogram. A cc cyl. lens will have the same effect, with the difference that the lengthening is in the direction of the axis, and if this is vertical, the parallelogram will be vertical. This ex-

plains why a cx and cc cyl. lens, laid together, axis upon axis, will counteract each other, and restore the parallelogram to a perfect square. When you take two cyl. lenses of the same strength, and place the axis of one vertically, and of the other horizontally, you destroy all the cyl. action, and retain only the strength of a simple spherical lens of the same number or strength as that of the cyl. lenses. Take, for instance, two lenses of —2 C, lay their axes crosswise, and you have —2 S which is neutralized by + 2 S, thus producing a plane lens. This is a simple way to find the number of cyl. glasses, when not marked by the grinder.

Some thirty years ago, a French optician, Galland de Chevreux, introduced such cross-cyl. glasses, claiming that they obviated that small degree of incipient astigmatism with which nearly every eye is afflicted. A careful comparison of them with spherical lenses will show the fallacy of this claim. This, and their high price, have brought them into disuse.

Cross-cylindrical lenses are yet used for the correction of aggravated and complicated astigmatism, but then they are always of different denominations; they are cx on one side and concave on the other, both of different angles according to necessity.

To determine whether a lens is cx or cc cyl., which is sometimes doubtful among those of lower strength, we have only to look through them at a vertical line, and move the lens to the right or left. If the line moves in the opposite direction of our motion, the lens is cx; but if the line follows, the lens is concave.

Generally, the grinder marks the axis by small lines at the border of the lens.

The use of cyl. glasses has increased lately to such an extent, that no optical establishment comes up to the re-

quirements of the trade without being able to fill correctly the orders of oculists. One tenth of all eyes are more or less astigmatic; and since oculists took the selection of spectacles in hand, the demand for cylindrical glasses is very great.

CHAPTER V.

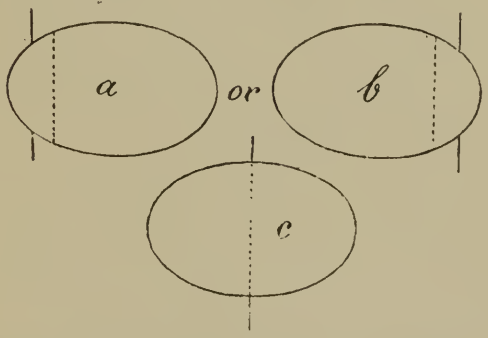
Optic Line and Centre, and How to Decentre Lenses.

Some twenty years ago, a traveler for a New York manufacturing house offered to me spectacles for sale which he called "Perfected," and when asked what he meant by it, said that the lenses were correctly set, the frames well tempered, and the whole spectacle *perfect*. To my great surprise, one glass of the first pair I examined, was badly centred. He excused himself by saying that he was not an optician, that he only represented the goods according to instructions given him by his employers, and promised that all goods I might order through him, should be without any fault whatever. He admitted further, that no member of his firm was a practical workman, but said that the factory was superintended by a competent optician. Now, if this foreman really understood the meaning of an optical centre in a lens, why did he not instruct the glass-setters how to be exact in the fitting of lenses to the frames, especially of those "Perfected Spectacles," for which they charged $4.00 a dozen more than for other goods of the same style and quality? I know not whether this name was invented only for the sake of extortion, or whether they charged so much more for the stamping of the temples, which was indeed nicely done in gold letters.

To be able to readily determine the *optic line* of a lens is more important for an optician than any other acquirement of his trade. It is the essential requisite for the correct manufacture of all optical instruments, — spectacles, opera-glasses, telescopes, or microscopes; the

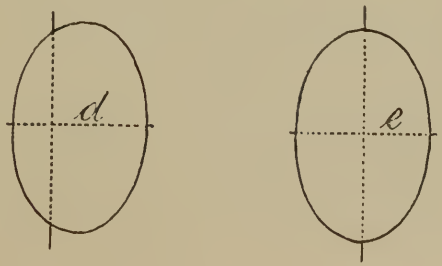
optical centre must have its right place and position, or the instruments will be incorrect and worthless.

The best way to find this *centre* is to look through the lens at a well marked straight line—drawn with pen and ink and a ruler across a sheet of paper. Hang this paper against the wall some four or more feet from you. Then take the lens between the thumb and first finger; extend your arm, shut one eye, and look with the other through the lens at the line. You will observe that the line is broken in the lens, and the more so, the nearer you move the lens towards its border. Figure *a* and *b*.



Now, move your lens slowly towards the centre till you find the line unbroken (Fig. *c*); mark this line with ink, and it will be the optic line of the lens in one direction; but you have not yet determined the optic *centre*. Now turn the lens in your hand 90°, so that the line on the paper and the mark on the lens form a right angle.

Proceed in the same way as before, and you will find, very often, that the optic centre is not always in the middle of the lens, Figure *d*.

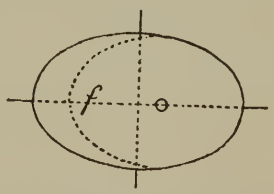


The two lines should cross each other in the middle of the lens, as they do in Figure *e*.

This test will do for spectacle lenses; but the test for scientific instruments is more elaborate, as we have seen in Chapter IV.

I would advise you now to take at random a dozen of spectacles from your stock in trade, and examine them as to the correctness of their optical centres. You will find that many of them, highly valued in the market on account of their trade-mark, are grossly incorrect, and good for nothing. It will cease to be a matter of astonishment that some of your customers could not see with one pair of spectacles, and yet found others of the same number pleasant and satisfactory.

To decentre a lens is an easy task for any one who understands the nature of the optic centre. As we have seen in Chapter IV, under the heading of "Prism," that we have to set them either "base in" or "base out," it is sometimes necessary, in order to overcome certain defects of vision, to decentre spherical lenses, and cause them to act like weak prisms. To fill such an order correctly, it is necessary to first mark the optic centre on the lens, then put the zinc-pattern (Chapter VI) as much as possible to one border of the lens, and make your mark around the pattern.



That border of the lens nearest the centre, is the base; and any order of "base in" or "out" is correctly filled, if you place this part (*f*) towards the nose or temple, according to order.

CHAPTER VI.

Fitting of Spectacle-Glasses, Their Filing and Drilling.

This chapter is the continuation of the foregoing, which explained the *main points*, concerning the correct fitting of glasses. We work blindfolded when we are unable to find the centre of a lens, and it will be by mere chance, if our work is correct. Rough lenses are not always well centred; if they were, we would have simply to cut the size we need from their middle, and there would be no mistake. Many of them will be found so much decentred as to be useless for size 0 and 1, and only fit for size 3 or 4, or they may be altogether worthless.* In a well centred lens the edges are equally thick on their opposite borders, and a little practice will enable the eye to see at a glance, or even without looking through it, whether the lens is decentred or not. This saves us a good deal of time, as the principal test is then quickly determined. But we should not rely altogether on the judgment of our eye in this regard, as it requires a good deal of practice to detect small differences in weak lenses.

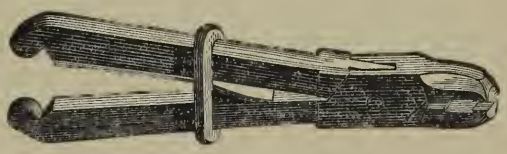
Any workman with good tools can perform in a short time more and better work than others who shuffle about the whole day long, wasting time and material, for want of proper implements. The most useful tool in setting glasses is the *model* or *pattern*, made of thin zinc. If you have not yet made use of them, prepare a set of the

* Except for lenses to be decentred.

different sizes and shapes of spectacles, as these come into your hands for repairs, and mark them according to the different sizes of the eye. Make a hole exactly in the middle, partly for purposes to be spoken of in the next chapter, and partly to suspend them on the wall within convenient reach, well assorted according to size and pattern. About three dozen will fully assort you, and will save you, in the course of years, an immense amount of trouble and time.

Another important tool is the *marker*, an instrument like a lead-pencil, mounted at one end with a small diamond. The marker is used to make a scratch around your pattern, after it is placed correctly on the lens. It will not cut the glass as a glazier's diamond, because it is intended only for scratching purposes, and is, therefore, very cheap. On heavy lenses it is best to mark both sides, to prevent the breaking of the lens inside the mark.

The next tool for our purpose is the *sliding-tongs*, an instrument employed by watchmakers and jewelers, who call it the "dog nose sliding tongs;" it is also used by opticians to chip the lenses.



I have found the largest size the best for almost all lenses; but very thin glasses can be chipped better with common flat pliers, as, for instance, glasses for lockets or watches, which you may occasionally be obliged to grind. The apprentice should practice this chipping well on pieces of window glass, before he attempts to shape a good lens, and spoil it, perhaps, by inexperience in handling the tool.

The proper way to handle this tool is the following: The tongs, held by the right hand, should be applied loosely to the lens, and worked as we do a pair of scissors, with the difference that at the same moment we close them, we also give the upper part of the tongs a slight inclination to the outside and downward. The lower nose is kept right on the mark by the middle finger of the left hand. This effectually prevents the lens from cracking inside the mark. The outside movement of the tongs throws the chips and glass-splinters from us, and thus saves the eyes from injury. But a fine glass-dust also rises from the lens, and is very pernicious to the lungs. Hold the lens, therefore, nearly at arm's length, and blow the dust off before you breathe.

As a rule, we should move the tongs outward; but we may come to a place which will not break readily, even by applying greater force. In this case we can sometimes accomplish our task with ease, and without the risk of spoiling the lens, by moving the tongs upwards, using the lower nose for the breaking, and the upper as a guide. This alternate turning up or down of the tongs should be well practiced by the apprentice.

It is hardly necessary to mention here that the stone has to be turned *from* you when grinding. I have seen only one jeweler (and he, too, styled himself "optician,") who turned the stone *to* him, as he had seen done by a street-grinder. Is it to be wondered that he complained afterwards of not being able to get a smooth edge on his glasses, or that they looked as if rats had given them the finishing touch?

I do not think it out of place to say here a few words in general about the grinding of lenses. Almost all manufactories grind them into a sharp bevel, which is in my opinion an unnecessary trouble, and, besides, shows very little sound judgment. The grooves of most frames

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are not pointed, but rounded off, whether they are made of soft material or metal; and the lens, to properly fill such a groove, should be also rounded off. This will have the double advantage of being less liable to crack, and less troublesome to finish. Sharp-pointed lenses easily split shell or rubber frames, when the latter contract in cold weather; or they themselves are chipped by metal frames, when they are tightly fitted. To overcome this difficulty, and to establish a practical method of fitting lenses to the frames, I will describe the method which I adopt. After the lens has been well shaped and sufficiently reduced by the sliding-tongs, I grind off the sharp edge on one side by passing it quickly over the revolving grinding-stone. A few revolutions will accomplish this, and will give it a small but distinctly visible bevel. Then I do the same with the other side, by turning the lens alternately edgewise, to take away its unevenness. In less than one minute my lens has a finished appearance, and needs now only the final adjustment. The edges of the lens have then a rounded form, and when set in frames do not show any roughness, as the polished surface of the lens touches the border of the mounting, thus relieving me of the trouble to polish the bevel, which, however, cannot be avoided when the lenses are thicker than the frames, or when the grooves are very shallow.

In regard to the present universally adopted habit of polishing the edges of lenses, I must confess that I do not approve of it, for the good reason that the reflected light from such bevelled surfaces is very annoying to the eyes, and can be easily removed by giving them only a fine ground finish, which the German and French call "matt." Even frameless spectacles could be made in this way, and would look equally stylish. But this reform can only be effectually introduced by the unani-

mous co-operation of the oculists in rejecting in future all glasses with polished edges.

The fitting of *bevelled glasses* into the groove of the frames is quickly done, and they are easily ground and shaped if they are of an oval or round pattern. Octagon glasses require more attention, especially when the frames are old and often repaired. The greatest care has to be taken with skeleton and grooved glasses, as the edge should be flat, and the bevel very small. The stone should be used till the lens is rightly shaped and the edge roughly flattened; we should then finish the lens on emery paper Nos. 3 and 2, and lastly on No. 1 and 0 for polishing purposes. If the lens has to be grooved, No. 3 is used only for the edge, but Nos. 2 and 1 for the bevel. It is better to finish the bevel before filing the groove, as a polished surface is less liable to chip in case the file should touch the edges. The grooving is always done with a round file, never with a four or three-cornered one. The file will soon be smooth if used dry; it is therefore necessary to wet it constantly either with water, turpentine, benzine, or *dilute sulphuric acid;* the latter is most effective. But even these will generally ruin the file after the finish of one pair of lenses, thus considerably increasing the cost and labor. The best fluid for the preservation of the file and drill for our purposes, is one that contains an excess of camphor. Any mechanic knows that a new file should not be used at once for filing hard iron or steel, without passing it first several times over a softer material as wood, brass or soft iron, to fill up the deeper parts of the file, giving strength to the exposed sharp points of it. Camphor renders the same service to our file used for grooving glasses, without interfering with its cutting qualities, if the fluid evaporates quickly enough to allow the camphor to clog up the deeper parts of the file. To do this by

passing it over lead, would cause it to slip without cutting the glass. The formula for this fluid is:

Spirits of Turpentine.....1 ounce.
Camphor Gum.....1½ "
Sulphuric Ether.....3 drachms.

The ether facilitates the solution of the camphor, and then greatly volatilizes so quickly, that the file would be dry after a few strokes, if the turpentine did not retard it for a while. Keep the file, therefore, constantly wet while using it, and it will do service for a good length of time.

The *drilling* or boring of glasses for skeleton or frameless spectacles is done by a drilling machine; but if you have none, it can be done also with a round file and this fluid. Select one almost of the size of the hole you need; break off the point, and commence the hole by moving to and fro the sharp edge of the file, previously dipped in the camphor preparation. Make a mark on the glass, then raise the file by degrees perpendicularly to the lens, and use it as a drill by turning it between the fingers. When the hole is half through, commence on the other side, and reduce pressure gradually, to prevent a sudden advance of the file when nearly through. The holes are finished off by a three-cornered sinker, much larger than the hole itself, which bevels the edges of it, and prevents the breaking of the lens by the subsequent insertion of the screw.

There are many devices recommended to shape drills for glass-boring purposes; all agree that they should never be pointed in the middle, but be rounded up, or flat like a chisel. My favored drills were always made of a round file (rat-tail), by grinding off two opposite sides, so that it had almost the shape of a square. Then holding the file at an angle of 60°, I smoothed the lower

surface with the oil-stone, forming a slanting plane, and producing a sharp strong edge to cut with. Another good drill is made of a three-cornered file, sharpened in the usual way, but with one corner taken off, so that the cross section of the drill near the point is that of a truncated cone, and the end of the drill of a narrow chisel-shape.

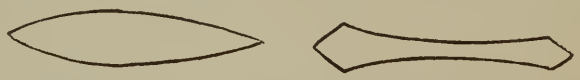
Not all files make good drills. Either they are not well tempered, or the grain of their steel lacks that peculiar cutting quality, which we find again in others. If you see, therefore, that your drill does not cut readily, throw it aside and try another file, till you find one that works well. I have often rehardened them, but generally without success; the steel was not precisely of that quality which is necessary to make a good drill. When you have secured such a file, take a jealous care of it; I have used some for years, and found them always reliable like old trustworthy friends.

CHAPTER VII.

Measuring of Compound Lenses, and Their Correct Setting.

Simple defects in the refraction of eyes can be corrected by spherical cx or cc glasses; and when their right number or strength is selected for each eye separately, and afterwards correctly set in suitable frames, such spectacles will always give full satisfaction. Nine-tenths of those in need of glasses are well suited with simple spherical lenses, and can be rightly served by the optician as well as by the oculist, who, if he is nevertheless consulted by over-anxious people, can do no more than we do: he uses his test-types to find the extent of the error of refraction, and selects the spectacles accordingly. But others require something more than an optician is able to do; these should be sent to an oculist, who, after a professional examination, will give his orders, and, generally, for compound lenses.

Compound lenses are combinations of spherical, prismatical and cylindrical glasses, of which two, or in some cases all three, are ground on one and the same lens. The most simple combination is when the plane sides of a prism are ground into the spherical shape of either cx or cc, without altering the action of the prism.



An order for such a lens will read for instance: + 3 S ⌒ prism 2°, or perhaps: — 2 S ⌒ prism 3° accordingly.

The combinations of compound glasses are so manifold that they have to be ground always to order, as no optician can have them in stock. We should never rely on the faithful execution of our orders by the grinder; we may have copied it indistinctly, etc. It is therefore advisable to remeasure all lenses before we fit them to a frame. Let us take the first lens as a test. We have here a spherical + lens combined with prism of 2°. I suppose that each of my readers has a trial-box with all the different lenses; if he has not, he should procure one as soon as possible, for no optician can do without it. We first take from our box a prism of 2° and place the thick end upon the thin one of our lens. We will see at once that the optic line, which was before near the border, is now in the centre. We then take — 3 S and place it on the other side of the lens; these three together must now be plane, or the lens is not correct.

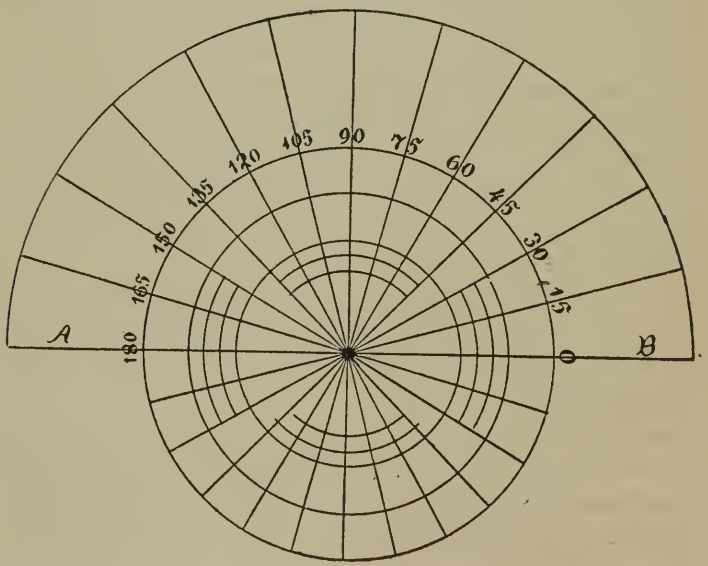
The next combination is the *sphere* with a *cylinder*. One side of the lens is ground spherically, the other side, cylindrically. Such an order reads: + 2.5 S ⌒ + 1.25 C. The test is the same as before. With — 1.25 C we neutralize the cylindrical action in this lens by laying the two axes so as to cover one another perfectly, and by adding — 2.5 S we must again have a plane lens. The grinder always marks the axes by little scratches upon the edges of the lens, so that we have no trouble in measuring them.

But how, when the grinder forgot to mark the lens, or when we are compelled to find the formula of compound spectacles, having no mark, handed us by a stranger to duplicate them?

Let us first see if they are decentred; if so, we will find one side of the lens thicker than the other, or that a horizontal line is elevated or lowered by turning the lens between the fingers to the right or left. When this

is the case, they are combined with a prism. We neutralize this prismatic action by trying different degrees of prisms till we get the optical line in the middle, or till there is no more breaking of the horizontal line. By turning the lens now, the optic line will not move up or down, as it did before the prismatic action was neutralized.

Keeping these two lenses in position, we notice whether the cyl. part of the lens is cx or cc, by moving it to the right or left in front of a vertical line (Chapter III). When this line follows our motion, the lens is concave, and has to be defined by a cx cyl. lens. The remainder of our lens is simply spherical, and easily measured. To prove the measurement, and especially to determine the right position of the angle of the cyl. part, we first neutralize the prism, and then the sphere, and lastly find the axis of the cyl. part by following the rule given in Chapter III. We now mark this line with pen and ink, and place our lens on the following figure:



The centre of the lens must be exactly over the centre of the circle, and the horizontal line marked on the lens from nose to temple must cover the horizontal line A B. We now observe in what direction the ink-mark points, and we have the degree of the cyl. axis. In making this proof we must hold always the outside of the lens upwards, not towards the paper.

All measurements of the physician refer to the position he takes toward the patient, his right is the patient's left.

I have made for my own use this delineation on strong paste-board, covered with white paper, and find it very handy and more accurate than anything I used before. The little lines are useful guides for finding the right position of the zinc-pattern, and dispenses with the labor of searching for the true centre through its hole.

Now, my young friends, I have tried to explain this matter in as few words as possible, and in the most practical way; but some of you may think it too complicated a task, and lose confidence in your own ability to overcome certain difficulties. Just try it, and if it takes you a whole hour to measure a compound lens over and over again, you will laugh at this "Sphinx" afterwards, when you will be able to solve the problem in five minutes.

It is absolutely neeessary to know well how to measure compound lenses before you can be able to set them correctly. I admit that there are difficulties which will puzzle the inexpert, and will lure them into a different calculation altogether. I give here a few illustrations: We have, for instance, a lens — 0.50 S ⌒ — 1 C ax 90°, the formula of which we do not know. By looking through the lens we see at once that the concavity is in excess of the convexity, if there is any at all. We first

look at a vertical line, and notice whether it will follow; if it does, and we pursue our investigation and correct the cyl. action by a suitable ex cyl. lens, we are on the right track. But if, perchance, we had turned the lens ¼ of its circumference, and had examined it in this position, which is at right angles of the true cyl. axis, we would have found that the vertical line did not follow, but acted as a ex cyl. lens, and we would have had to make the correction in this case with a concave cyl. lens. The consequence would be that we had made cross-cylinders (Chapter III), and adding — 1 S to the — 0.50 S, which was before the real amount of its spherical concavity, the formula found would be — 1.50 S ⌒ + 1 C ax 180°. In order to detect the mistake, all that is necessary is to try the lens with + 1.50 S, and we will see at once that we are wrong, because our lens of only — 0.50 S will not be neutralized by the test-lens + 1.50 S.

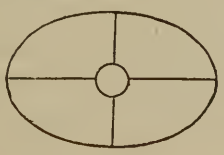
For another test let us take — 0.50 S ⌒ + 2 C ax 180°. The cyl. axis is easily detected in such a lens by its shape; but for argument's sake I suppose we have fallen into the same error, and again produced cross-cylinders, thus turning + 2 C into + 2 S. Then we have to add + 2 S to — 0. 50 S, which would give + 1.50 S, and our formula would be + 1.50 S ⌒ — 2 C ax 90°. If now we take our lens and cover it with a test-lens of — 1.50 S, we shall see our error clearly.

We take another lens: + 1.75 S ⌒ + 0.50 C ax 90°, and by the same faulty process we will get + 1.25 S ⌒ — 0.50 C ax 180°; but by covering our compound lens with a test-glass of — 1.25 S, we perceive that we have made a gross mistake, and have to recommence our investigation 90° from the line we mistook for the true cyl. axis.

Such an incorrect lens would be utterly useless to the

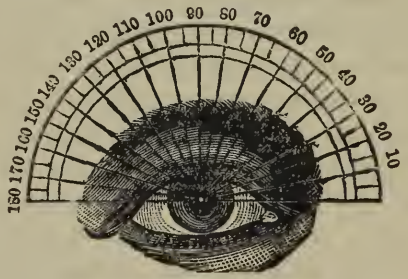
patient for whom it was prescribed, because it is intended to correct where there is no correction necessary, and leaves the really impaired axis of vision unimproved. It is, therefore, well to measure compound lenses first in one direction and afterwards 90 ° from that line, when it will be an easy task to find the true axis of the cyl. part of the lens. In order to find the formula, the axis should always be marked by small scratches at the border of the lens, or by pen and ink on a lens already fitted.

The fitting of a compound lens to a frame next lays claim to all our attention, if we will do justice to the general rule, i. e., to bring the spherical centre before the pupil of the eye. When we have marked the cyl. axis in ink across the whole lens, and have neutralized the cyl. action by its opposite, we must next observe where the optic line crosses the lens 90 ° from the cyl. axis, and mark it likewise in ink, but in a manner different from the line of the cyl. axis, say by little dots. We now lay that point of our lens where the two lines cross, exactly over the centre of the test-figure, turn the axis of the cyl. to the prescribed angle, and mark by little scratches at the edges of our lens where it touches the horizontal line A B. These marks are guides to direct us in regard to the nose-piece and temple. We must take care that the hollow side of the lens lies upon the paper, because that side will be towards the eye. Our zinc-pattern, after which we mark the lens, must have a hole exactly in the middle, and a marked line from the nose-piece to the temple.



Through the hole we can see the point where our ink-marks cross; we put the line of the pattern so that its continuation strikes the scratches made before as a guide for the nose and temple, and after ascertaining once more by careful examination that everything is right, we continue our marker around the pattern. Before chipping off the superfluous part of the lens, we take a small wooden ruler, place it on the lens, touching the two marks for nose and temple, and make two other fine scratches inside the mark just made for the size of the lens, long enough not to be ground away in the finishing process. After the chipping, we have only to pay attention that our lens retains a nice oval shape, and that the edges are well bevelled.

Any optician who follows these instructions cannot fail to give full satisfaction to the most exacting oculist, no matter at what angle the axis of the lens has to be placed. I believe that some opticians are careless in marking the true centre of the lens, and use, to find the angle, designs similar to the following:



I republish this cut as a sample of the incorrect manner in which they are generally made, and to guard against their use by any jobbing optician.

In the "Jewelers' Circular and Horological Review" of November, 1885, I find on page 312 the strange complaint of a well-known oculist, saying: "You will seldom

find a workman who can exactly set a cylindrical lens at the axis required, unless the axis named be 180° or 90°. You will probably have to tilt the frame a little, either up or down, to obtain the exact position required. That they set more lenses wrong than right, has been my experience."

If his opticians use the above design to find the angle, their lenses must, of course, be incorrectly set, except in those two directions, as they are the only correct ones. It is, therefore, no wonder that the "Doctor" finds fault with his opticians.

It may be deemed by those of my readers who, by reason of their education and long experience, are familiar with both the science and art of our business, that I have rendered myself tedious by entering too minutely into details, and being less concise than the subject demanded. While hoping that no one may fail to find something to repay him for the perusal of my book, I beg to say that these pages are directed not only to the proficient, but also, and perhaps more so, to the beginners in our difficult trade. I have aimed to elevate them to the full requirements of our occupation; with this view I have presented some things which might otherwise have been omitted, and, to be well understood by them, have been, perhaps, in some places, more than ordinarily diffuse.

CHAPTER VIII.

Selection of Spectacles: Pupil Distance, Nose-Bridge, Reading and Street Glasses.

This chapter is written only for young opticians and such persons as have not yet acquired sufficient experience in the selection of spectacles, to overcome the many vexations incident to their particular trade.

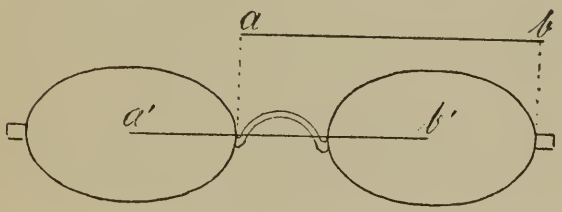
The two essential parts of spectacles are the *lenses* and the *frames*. It is not my object here to give a treatise on the selection of the proper lenses for the correction of the many deficiencies and irregularities of the eyes, as this would compel me to enter into their anatomical construction and their defects, which can be found ably described in the many medical books published for this purpose by eminent physicians. My object is to give an inside view of the practical and mechanical part of our trade, and leave the theoretical portion to "Specialists."

I must refer first to the *pupil distance*, as this is the main point of a good fit of a pair of spectacles. Pupil distance is the length between the two pupils, measured from the middle of one to the middle of the other. This distance is never smaller than two, nor larger than three inches. The eyes of little children, as well as those of the largest men, are within this compass. The average pupil distance of a grown person is $2\frac{3}{8}$ or $2\frac{1}{2}$ inches, and these are the standard sizes the manufactories use for most spectacles they make. An optician is, therefore, obliged to have for any emergency an assortment of all the different widths ranging from 2 to 3 inches. Chil-

dren require 2″ and $2\frac{1}{8}$″; boys and young girls $2\frac{1}{4}$″ and $2\frac{3}{8}$″; grown persons with small faces use mostly $2\frac{3}{8}$″. A full face needs $2\frac{1}{2}$″ and $2\frac{5}{8}$″. Near-sighted people have generally a large pupil distance, and very often require as high as $2\frac{3}{4}$ inches. I have had in my extensive practice only three customers whose pupil distance reached fully 3″, and all of them were near-sighted. I myself use $2\frac{7}{8}$″, and share the same fate; I, too, am near-sighted.

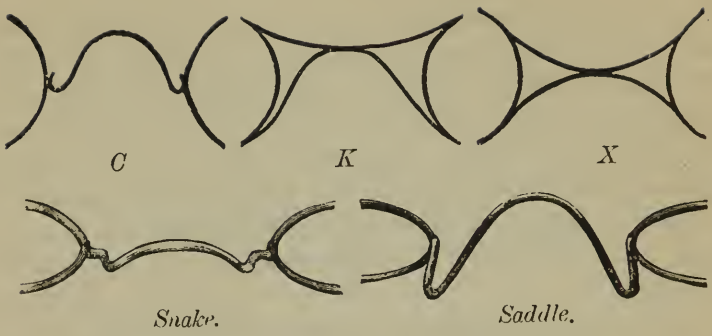
An ordinary dealer has a fair assortment with spectacles or frames from $2\frac{1}{4}$″ to $2\frac{5}{8}$″, most of them of $2\frac{3}{8}$″ and $2\frac{1}{2}$″ pupil distances.

A simple way of finding the size of spectacles is to measure the *length of the nose-piece and one eye*, which gives exactly the true pupil distance:



because if you shift the line *a b* to the left, so that *a* is vertical to *a'*, then *b* will be vertical to *b'*, which are the true centres of the frame.

Another important point is the selection of a proper *nose-piece*. People with a low or shallow bridge should not, or rather cannot, wear eye-glasses; and even spectacles of the ordinary size are not satisfactory, if the nose-piece is not shaped so as to correct the deformity of the nose. Formerly there were only three nose-pieces in use, the C, K and X, to which lately have been added the *snake* and *saddle* nose-pieces.



The X and snake nose-pieces are the best for low noses and street glasses; the last is especially useful in removing the glasses far enough from the eyes to free the eyelashes from coming in contact with them. The only objection to most of these nose-pieces is that they are rather thin, and consequently cut the nose, if the skin is tender, as is the case with children and ladies. It is strange that means are sometimes employed to remedy one evil by the substitution of another. Instead of making the nose-piece broader, Dr. Hubbell invented a nose-guard, a broad attachment to the nose-piece, which, of course, prevents the cutting of the nose, but at the expense of its look.

If the nose-pieces were made sufficiently broad, well-shaped and polished, they would not need any lining of turtle-shell or cork, such as are made lately at some additional expense, while the broader nose-pieces, answering the same purpose, can be manufactured at the same cost as the thin ones now in use.

Reading spectacles should always be in such a position, as to permit us to see through the middle of the glasses without being obliged to bend our head down or forward. We should be able to see at an angle of 45° through the middle of the glasses with our head straight, and by merely lowering our eyes in that direction. These glasses must be placed considerably lower than the street glasses, which, on the contrary, enable us to see through the middle of the lens when looking straight ahead. The military rule for this position is that the eyes should strike the ground at forty steps from us, which is about one hundred feet. Near-sighted persons should be fitted in this way. It looks very bad when the street glasses sit too low, and oblige the wearer, in order to see through the glasses, to throw his head back, as if he were star-gazing.

In regard to this stooping position for working purposes, I may mention here the reason why people should not bend their head forward, but keep it erect while reading, etc. Any medical book will inform you that the *arteries* which carry the blood from the heart to the head and all the parts of the body, are situated far beneath the surface, and that those blood-vessels which you can see just below the skin are *veins* which conduct the blood back to the heart. Now feel the muscles of your neck when erect, and again when stooping; they are soft and pliable in the first position, and hard and stiff when you bend your head forward. The arteries being situated below the muscles, their action is not influenced by the changes of the latter from the contracted to the relaxed condition; but the circulation in the veins is considerably interrupted by their being compressed to a much smaller size than before. What is the consequence? The pumping of the blood into the head goes on uninterruptedly; but the flowing off to the heart is ob-

structed, and we sooner or later suffer from headache, get dizzy, and have to stop work. How many times is a spectacle-dealer puzzled by such complaints of his customers, not knowing how to correct it? Trying in vain stronger numbers ! !—till at last these people by chance find among the cheap, common spectacles a *better fitting frame*, and, of course, also temporary relief. We not only lose this ill-pleased customer, but drive him to the conviction that twenty-five cent spectacles are just as good or better than two-dollar ones. We are the cause of his at length ruining his eyes by the use of these common spectacles, through our ignorance of the nature of his reasonable complaints. Direct, therefore, great attention to the fitting of suitable frames.

It is hardly necessary to mention that it is absolutely necessary to examine both eyes separately, and to correct any error of refraction by the proper lens. But there are cases beyond the sphere of opticians, i. e., when it is impossible to make the right diagnosis without preparing the eye for such an examination. These patients should be turned over to an oculist; it would be an act of "charlatanry" on our part to pretend to do full justice to such cases. Confine your skill to the limits of your trade, and you will be convinced that it requires all your knowledge, intelligence and energy to fill the place of an expert optician. Over-ambitious young men may commit the error of trying to combine the two branches of an oculist and an optician as far as spectacles are concerned; but is it not the mistake of a builder who would be his own architect, the apothecary, his own doctor? The public in general fares better if these branches are divided, and ably represented by competent specialists: on one side the scientific oculist, on the other side the skillful optician, both experts in their particular branches. If we play oculist, why

should not the oculist play optician, and keep a stock of spectacles on hand? Therefore my advice: "Suum cuique."

CHAPTER IX.

Double Focus. Single and Split Glasses, Relative to Optical Line or Centre.

The failing of our eyesight manifests itself by the gradual lengthening of the focal distance. At first we could see well at 14″; next we are compelled to hold our book or paper at 15″; afterwards at 16″, etc.; and the progress of the lengthening of our focal distance, slow at first, soon takes a wonderfully rapid stride, if we hesitate to substitute by spectacles that part of our power of vision which is irrevocably lost. We are reminded here of the common adage: "One stitch in time saves nine"; i. e., the early use of spectacles, when their assistance is necessary, saves our eyesight from its otherwise rapid failure. Nine persons out of ten, who come for their first glasses, confess that they have put off the use of them as long as possible, but have to yield at last. They are not aware of the great blunder they made by taxing their diminished power of vision in the same degree as they did when their eyes were enjoying yet their full strength.

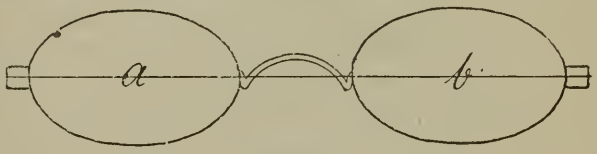
A well-known fact of our "losing sight" is the improvement of distant vision; the sight is going away from us, we gain at the distance what we lose near by. Let us see fifteen years later what has become of our customer's eyes and his spectacles. The gradual failing of his eyesight has compelled him to increase the strength of his reading glasses, till he uses now + 2.50 Diopters (or + 16 inch focus) for near vision; but his far point has also removed, and he finds it impossible to

distinguish the features of the minister, or the faces of people in the street 50′ or 100′ away from him. He asks for street glasses. And here arises the question: Is it advisable to combine reading with distance glasses? The most rational way is to take separate glasses for each purpose. Most people will follow your advice, and change their glasses accordingly. But we have to deal also with nervous, quick-tempered and impatient customers, who grumble at the slowness of steam, and will have everything go by lightning. They imagine that they have no time to change their spectacles; and indeed some people have not. There is the accountant, whose entries in the ledger from the journal force him to look at items 4′ to 6′ from him. He cannot keep a comfortable seat and accomplish his task, if he has to jump up, and bend his body, and stretch his neck right or left, to check off and make a correct entry. There is the paying-teller, who must have a sharp eye on his money and the party receiving it. There is the engineer watching his engine, and looking every now and then at his steam-gauge; the teacher, the minister, the orator, the clerk, the lawyer, and many other persons, who find it absolutely necessary to be enabled to see well at a glance far off and near by. Can we accommodate these people without injuring their eyes? We can, with double-focus spectacles, each glass adapted to its special purpose, the upper part for distant, the lower for near vision. These spectacles are called "Franklin glasses," because Benjamin Franklin was the inventor of them.

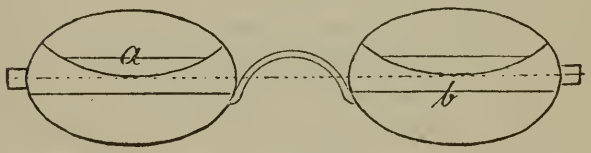
There are two kinds in use: the double focus *single* lenses, where the upper part is ground off to a weaker focus, and the *split glasses*, where the distant and near lenses are cut through the middle (or optic line), and finished so that the split forms a straight line in the frame from temple to temple. The optic line in these

glasses is, therefore, right on the split. The wearer, of course, is obliged to look below or above that very line where the eye is most at ease, and where only it feels comfortable, according to facts demonstrated in Chapter IV.

The double-focus *single* lens has another more serious defect. It confuses the wearer in regard to the true position of things. If we look at a straight horizontal line first through one part of the lens, and in the next moment, by moving the lens, through the other part, we observe at once that the line is considerably displaced. It is elevated or lowered as we look at it alternately through the upper and lower part. Both parts of the lens act as prisms, bases in the middle.



Split.



Single.

If the dotted line in the double-focus *single* lens is the true position of an object, we see it through the upper lens at *a*, and through the lower at *b*, but never where it really is. People who wear such glasses, may, by looking, while descending the stairs, through their lower part, reach the bottom sooner than they expected; and if they have not lost their spectacles by the accident, may stare in bewilderment through the upper part at the place whence they came so suddenly. This has happened more than once.

The relation of distant glasses to reading glasses is calculated by the following rule in the inch measure:

Multiply by 3 from + 16 to + 11
" " 2 " + 10 to + 6
" " 1½ " + 5 down.

When people wear + 16, we try + 48 or + 60
" " " + 11, " " + 30 " + 36
" " " + 10, " " + 20 " + 24

and we will find that one of these numbers is generally correct. In all cases where people insist on having double-focus glasses, we should persuade them to take split glasses. Some, however, think themselves smarter than the doctor, and will persist in using double-focus *single* glasses, because they look better. Let them have their way, and be happy.

CHAPTER X.

Colored or Tinted Glasses.

It took the human race very long to invent suitable appliances for the protection of injured and diseased eyes. Every other want was early cared for, according to existing means and ability; but we look in vain for anything more ingenious than the simple application of rags or a handkerchief to an inflamed eye. We may believe with certainty that men, when hardly above the level of their surroundings, used the skins of animals to protect themselves against the inclemency of the weather. But among the thousands of improvements they made with advancing civilization, there was none to benefit the ailing, suffering eye to any extent. This organ, so delicate, and yet so recklessly overtaxed, is nevertheless a most obedient slave, always ready to perform its task from morning to night, till finally, unable to stand any longer the effect of the glaring, piercing light, or bear its other hardships and abuses, it closes its shutters, and alas! what becomes of its owner, so suddenly deprived of its services? The terms, *blind men and beggars*, are almost synonyms, and indicate the great misery attending the loss of sight. Fortunately we live in an age in which science has also investigated this, so long neglected part of the "evils that befall mankind," and we can say with pride: *the blind shall see*, not by a mysterious wonder, but by the scientific skill of experts.

Among the most useful modern appliances to relieve the sufferings of an afflicted eye are the so-called *Protection Spectacles*, which are set with colored lenses, to

soften the excess of light, otherwise so annoying and hurtful. Since spectacles were invented, people have made experiments with different colors, giving preference at one time to this, at another time to that color, according to fashion, entirely disregarding optical laws, till they have settled for the present, with scientific reasons, upon the tint of *smoke*. To comprehend this question thoroughly, we must direct our attention first to the theory of colors in general, and see what we understand by the term "spectrum."

When we speak in an optical sense of colors, we exclude, of course, the pigments used by painters, who include among them even *black* and *white*, which are no colors at all. Black is the absence of light, and consequently of colors; white is the undivided light, containing all colors so combined that the different tints totally disappear. White light is, therefore, called "colorless," although it needs only to pass through a certain medium to be resolved into the brightest colors, as is seen in the rainbow, where the falling drops act as the decomposing agent. The rainbow is a fair specimen of the *Solar Spectrum*, showing the seven spectral colors, red, orange, yellow, green, blue, indigo and violet. To these should be added *brown*, outside of the red, and *gray*, outside of the violet. By means of a prism we are enabled to produce this spectrum to perfection, and to investigate the particular properties of each color separately. We thus find that red is least refracted. It forces its way forward like a heavy ball or shot, while violet is the most refracted, yielding to the obstruction it encounters in passing through the prism. Scientists have found that the waves of red are nearly twice as long as those of violet, and this accounts for the impetuousness of its ray, which almost overcomes the interference of the prism. The waves of the other colors be-

come gradually shorter, up to violet; and as the smaller waves act more gently upon the tender tissues of the retina, we might guess with some probability that violet would be the softest color to the eye. This would be a gross error. There is a decided difference in the effects of colors on the eye. It is pleasant to look at the dark green of a meadow or the foliage of trees; but it is very trying to use green spectacles, because our eyes are then constantly under the influence of one particular color. In fact, no color is hurtful to the eye as an object to look at; but if a special color is used as the medium to look through, it always acts more or less injuriously, as the shade is lighter or darker. There is no exception to this rule. We must bear in mind that a healthy eye is able to endure the full force of the whole light, and that any division and exclusion of its essential components will act detrimentally, as would be the case in breathing only oxygen or nitrogen separately, when the mixture of both in a certain proportion is a vital condition of our existence. No separate color is, therefore, a proper substitute for white light, for which our eye is constructed, and so well adapted as long as it is in a normal condition.

But when the eye is impaired, and cannot stand the full strength of light, should we not shut off the most hurtful part of the spectrum, and allow only the softer colors to act upon the tender organ? Does not the physician regulate the diet of his patient by depriving him of certain food? Certainly, so it seems at first to any superficial observer, but even the most rigorous diet does not deprive the patient of any of the necessary elements of his nutriment; only quantity and form are modified. Of the fifteen elementary substances our body contains, the four most essential are oxygen, hydrogen, nitrogen and carbon. To eliminate from the diet of a

patient one of these four elements, would not be more irrational than to suppress any color of the spectrum in favor of another. Neither green, blue nor violet can be substituted for the peculiar union of all colors producing white light. Any shifting of the finely balanced ingredients of white light will act fatiguingly or even perniciously upon the eye. Those of my readers who understand chemical formulas will readily see the point in question. The (old style) formula of *sugar* is expressed by $C_{12} H_{11} O_{11}$. Now take two atoms, each, of hydrogen and oxygen from the molecule, and we have *vinegar* $C_{12} H_9 O_9$. By the same process "sweet" light may be made disagreeable by smothering one or more colors of the spectrum, or rather by increasing the effect of one particular color at the expense of the others.

I have treated this subject more elaborately than would have been necessary, if other writers had given it the close investigation demanded by the importance of the scientific principles upon which it is based, and the practical service which a thorough knowledge of them will enable us to render those whom it is the object of our trade to protect or assist.

We have seen that the exclusion of particular colors of the spectrum does not answer our purpose. It remains, therefore, to decide what can be done to protect the suffering eye from the injurious effect of light, without interfering with the essential combination of the thermic, electric and magnetic qualities of the sun's rays, which peculiar combination agrees exactly with the construction of the eye, as the milk of the mother agrees with the constitution and healthy development and growth of her infant. The most rational method is to diminish the whole amount of light by *smoked glasses*. These do not alter the proportion of the different col-

ors, and produce no change in their vibrations. They only lessen the amount of light without disturbing the proportion of its elements. The whole spectrum is thus uniformly reduced, and nothing is changed by smoked glasses but the strength of the excessive light.

To show that no special color by itself will satisfy the eye, I remind the reader here of the well-known experiment of saturating the eye with one color by excluding the others, and observing how eagerly the eye absorbs the complementary color after the test-color is suddenly removed. The easiest way to make this experiment is to cut from colored paper round pieces of the size of a silver dollar. Lay one of these circles upon white paper, and look for a while steadily at it, the eyes one foot from the colored circle. By removing this quickly, and looking always at the same place, we will see distinctly the complementary color. If the circle was red, we will see instead of it a green one, which color is complementary to red. A yellow circle will produce violet; blue produces orange; and green will show red. The eye seeks to be relieved from the strain, and is, therefore, much in need of the missing colors. It takes, indeed, a good while before the eye recovers from the fatigue, and is again able to receive the white light without seeing colors. This experiment was known for many years, but nobody has yet drawn that lesson from it which it so clearly teaches. Medical books leave the selection of a special color an open question, and permit the patient to choose for himself, or they are prejudiced in favor of one particular color, as the celebrated Dr. Graefe was towards blue glasses, rejecting smoked almost entirely.

It is needless to waste words further in regard to green, blue or violet spectacles, still manufactured and sold extensively to persons, who are always on the look-

out for something different from what others sell, and which are recommended the higher, the less such "opticians" know of the science of their trade. I conclude this chapter by citing some sensible remarks of Arthur Chevalier: "The great trouble is that the manufacture of colored lenses is not yet scientific. There are thousands of different shades, due to the careless way in which glass is made. If scientific glass-manufacturers would take it in hand to produce a clear colored crown-glass, and would publish their formula, after their glass has been approved by leading oculists, all colored lenses could be limited to *one dozen* different shades, classified with the same certainty as we define now the white lenses by diopters. As colored lenses have only the object of softening the excessive light, it is rational to imitate the common practical way of shutting off the light by closing, according to necessity, the blinds of our windows or turning down our lamps. This is done by smoked lenses in their different shades. There is hardly any exception in all the many defects of diseased eyes where smoke would not do all services expected from colored spectacles. Even healthy eyes are in need of them in countries covered with snow, or where the intense glare of a tropical sun affects them. This refers exclusively to people who are obliged to expose themselves only occasionally to the disadvantages of the climatic severities, and not to those who are habitually accustomed to them. The Esquimaux make for themselves from wood a kind of coquille spectacles with a slid in the middle, to allow only a limited quantity of light to enter the eye."

Smoked glasses are absolutely necessary when the eye is inflamed, after most operations, and in other cases decided upon by oculists.

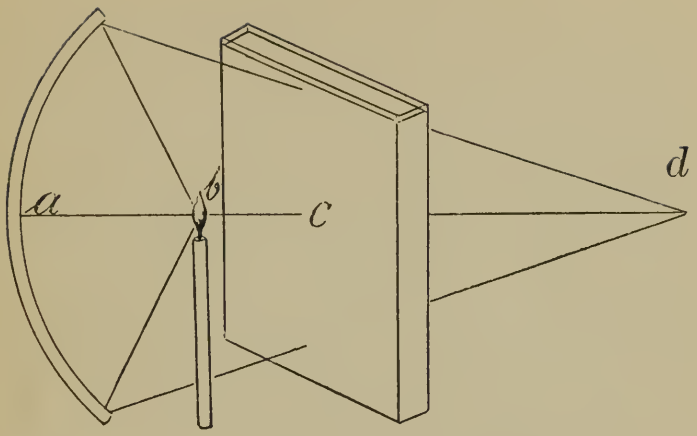
CHAPTER XI.

The Proportion of Caloric Rays in the Different Kinds of Light.

According to the old emission theory, light is a compound *matter;* but, according to the new undulatory theory, it is a compound force. It is a mixture of luminous and caloric rays, and is also a combination of the different colors. To resolve light into its colors has been a comparatively easy task, especially since the properties of the prism have become known; but the complete separation of luminous from the caloric rays is yet a matter of investigation. Eminent scientists have labored long to isolate one from the other, but with only partial success. Light, passing through an ice block, or through plates of mica, is not entirely deprived of its caloric rays, although they are absorbed to a certain extent, but by means of a strong burning-glass you will detect enough of them to be sensible of their presence. Some explorers have succeeded in completely absorbing the luminous rays, and showing at the same time the presence of the caloric rays in their full strength.

The following experiment was communicated to me by Professor Pepper, of England, in 1872, when he, on his American lecture tour, passed through New Orleans. I repeat it here as he explained it to me. I have never tried this experiment myself. I remember with great pleasure his able lecture on "Light and Heat," illustrated profusely by novel and highly interesting experiments. (*See Cut on next page.*)

The candle *b* stands between the glass-jar *c* and the



concave mirror *a*. The rays of the candle are thrown by the mirror on the flat jar, filled with a solution of *sulphuret of carbon and iodine*, which completely absorbs the luminous rays. You cannot detect through the jar the least trace of light; but if you hold your finger at the point *d* you will find that the caloric part of the light is concentrated there most keenly. This shows that the liquid absorbed only the luminous rays, and allowed the caloric rays to pass through without perceptible interference.

In the same manner that luminous rays are modified or intercepted while passing through bodies of different degrees of clearness, the caloric rays are also more or less intercepted by different substances. Mica, for instance, absorbs the greater part of the caloric rays; but the only substance which allows all caloric rays to pass without any obstruction is clear *rock-salt*. Experiments with prisms of this salt have demonstrated the fact that light passing through such a prism gives two spectra, one by the luminous, another by the caloric part of the light, with the remarkable difference that the *red* line of the

caloric spectrum is as broad as all the other colors combined, from orange to violet. This experiment is an undeniable proof that the caloric and luminous rays can be separated, and that both kinds of rays are subject to the same law of nature, the undulatory or wave theory.

This theory defines light as *motion* of such an intense velocity that we can express it only in figures, but are utterly unable to comprehend it. Imagine that we were able to build a machine of indestructible material, and had the power of increasing its revolutions indefinitely. We put it into operation. As long as we can follow its movements with the eye, we have *common motion*. We can follow with our eyes a stone thrown at some distance. This also is common motion. Let us now increase the speed of our machine thirty-three revolutions a second. The eye can no longer follow it, but the ear discerns a low hum, which becomes louder as the machine gradually moves quicker. We have *sound*. A rifle-ball is not seen, but we hear its whistling noise. When the tone has reached its highest pitch (38,000 vibrations in a second), our ear is unable to perceive any further increase; we feel then the effect of *heat*, and soon see a violet glimmer, then a transition through blue, yellow and red into white. We now have *light*. The vibrations have increased to many thousand billions a second. If our machine is not melted by this time, and is still running with increasing speed, we had better keep at a safe distance, for the next action will be the emission of *electric* sparks and lightning in all directions.

Here science ends; and here is the limit of all power and force we can explain or comprehend. But if we allow our imagination its widest range, and look upon this experiment only as the symbol of the universal, sublime power, does it not give us a faint idea of the proper

mode of attaining to the knowledge of this *ultima ratio*, the incomprehensible omnipotence?

We have seen that light and heat are always combined, that there is no light without heat, for phosphorescence cannot be regarded as light. There is natural light as the sun, and artificial light. In ancient times people used torches or splinters of pine wood to light their rooms; these enabled them to distinguish objects but faintly. Oil-lamps and candles were a great improvement, and by their aid people could continue their work after sunset. Gas was a still greater improvement; but the greatest of all is undoubtedly the electric light. I think that with this we have reached the climax of lights for many years to come. But what percentage of caloric rays is contained in these different lights? Every one has observed that in a well-lighted theatre or ball-room the light is quite dazzling, although it cannot be compared to daylight. It is, therefore, not the excess of light which fatigues the eye, but the excess of the caloric rays which makes it so unpleasant. The cause of this is easily explained. A small quantity of light dilates the pupil; the heated rays enter more freely, and soon cause the eye to smart and ache.

Sunlight is the coolest; it has only 70 % of caloric, and 30 % of luminous rays. It is perfectly white or colorless, and is the most agreeable to the eye. The caloric part of it is greatly modified by the moist atmosphere it has to penetrate, and by repeated reflections. The emmetropic eye is, therefore, well able to bear its effect the whole day long without fatigue.

The *Electric light* comes next. It is slightly colored, has a violet-bluish tinge, and contains 80 % of caloric rays. If this light is steady, and the eye is shaded

against the entrance of the direct rays, it will rank next to the sunlight.

Then comes the ordinary *Oil-lamp*, including the improved coal-oil lamps, which have 87 % of heat rays.

Gas, with its 90 % of caloric rays, is the best agent opticians could employ to increase the sale of spectacles. The light is yellow, as we readily see when a gaslight is near an electric light; besides, it is very often flickering and unsteady. For home use, a good coal oil lamp is preferable under all circumstances.

The poorest light of all is the *Alcohol lamp*, which has only ½ % of luminous rays, and is absolutely unfit for seeing purposes.

In recapitulating the foregoing by comparing artificial lights with sunlight, we find first that they are always colored; and secondly, that they contain an excess of heated rays, i. e., there are less luminous and more caloric rays in them than in the colorless and comparatively cool sunlight. And as we know that heat is the principal cause of weariness and fatigue of our eyes, we have here a guide in selecting for working purposes just that light which will tax them the least, and will not spoil them prematurely.

CHAPTER XII.

Second Sight, Its Cause and Final Course.

Occasionally we see old persons rejoicing in a renewed growth of hair after having been bald-headed for years. Their natural hair again appears as it did in their youth; not white and bleached, like the last remnants, but blonde or dark colored, and even curled, a luxury they never dreamt of in younger years. And it is not only the hair that manifests a certain kind of rejuvenescence, the toothless jaws produce another set of teeth, and what is still more wonderful, the eyes regain their youthful strength, and these "old lads" lay aside their spectacles and read once more without them as they did in their younger days. The reproduction of hair and teeth is generally little noticed by the skeptical public, as these changes can be produced by wig-makers and dentists; but the reading without spectacles at that age, by those whom people have seen using them so long, cannot be the result of any deception, and that there has been a real change in their eyes, is a fact that cannot be denied.

This freak of nature is not the renovation of the worn-out machinery, as many people think. It is the last desperate rise of an extinguishing light. Let us look into the cause of it. The lens of a normal eye has a certain convexity which in the length of time flattens, and compels people to remedy this loss by convex spectacles. The more the crystalline lens flattens, the greater must be the convexity of the spectacle-glasses. One necessitates the other, up to old age. But it hap-

pens now and then that the lens no longer flattens. On the contrary, it is contracted and rounded up again by a degeneration of its tissues, causing the phenomenon of the so-called "Second Sight." Such people have to take, gradually, weaker spectacles, till they are able at last to read without them, and are even benefitted by concave glasses for distant vision. If this changing process of the eye would stop here, and would last many years instead of a few months, it would be well; but this apparent improvement of the eyesight is only the manifestation of a serious disease of the crystalline lens, which is undergoing an alteration similar to that of an orange, when its juice dries up, and it gets hard and wrinkled. So it is with this delusive present, which unveils once more the faint image of our youth, only to fade away the more rapidly from our eager grasps, in less time than it took to develop itself. The humor of the crystalline lens loses its transparency, the pupil, which was formerly jet-black, appears grayish, and cataract has fairly commenced to destroy sight for ever. Is it not a wretched delusion which makes people rejoice for a while, and then ends in the misery of total blindness?

I advise my readers, who have to deal with such customers, seeing the advance of this fearful visitation, not to be indiscreet, and wantonly dispel their happy deception, as nothing in the world can arrest the final course of their trouble. You may advise them not to read or sew at night, and to spare their eyes as much as possible. When in the first stage of incipient cataract, bright light begins to annoy their sight, give them smoked glasses; these neutralize best the scattered rays, which pass through the infected lens. Do not lose patience by their renewed attempts to find some relief by changing their spectacles. Have always a kind word for them, and as you cannot help them materially, let them have the full benefit of your benevolent sympathy.

CHAPTER XIII.

History of the Invention and Introduction of Spectacles.

Old tradition credits Phœnician merchants with the invention of glass. This nation occupied a part of the coast of Syria, between the Lebanon and the Mediterranean sea, northwest of Palestine, and was already widely known at the time of Jacob, the patriarch, about 1750 years before Christ. But it seems glass was known before that time, as there has been lately found below the ruins of old Nineveh a lens evidently used for optical purposes. The knowledge of the manufacture of glass was early acquired by the Egyptians, who improved on it, and made even colored specimens. After the Romans conquered Egypt, this art was introduced into Italy, where they soon learned to make plate-glass, and also produced a kind of glass which could stand without injury the effect of hot fluids. They also claimed to have known a glass which was malleable, and to a certain degree unbreakable. A good story in relation to this states that a man once demanded an audience from the Emperor, and presented to him a goblet of glass. The Emperor was highly pleased with the splendid workmanship of it, but when it passed from hand to hand among the courtiers present, it accidentally fell to the floor, or, as it is also related, the artist himself threw it willfully down. It did not break, but was badly dented. The man repaired it immediately with a small hammer he had

brought along with him. It is a pity that this important invention is entirely lost. One Roman historian reports that Nero could not see very well, and that he made use of a large jewel in the shape of a lens, to enjoy a better sight of the fights of his gladiators. But this was not imitated by others, and it is narrated by the historian only as one of the many strange extravagancies of this most remarkable man of the Roman empire. *

For the next one thousand years no advance in science was made. Many old inventions were forgotten for awhile; some are lost forever, and we only hope that somebody will be fortunate enough in future to rediscover by chance or by the aid of advanced science what an accident once so luckily revealed to our ancestors, who, however, did not appreciate it, but buried their pound like misers. The investigating mind was for this long period turned into the opposite course of training. Instead of studying the hidden forces of nature, and enjoying its bountiful gifts which an exceedingly friendly providence had put into an easy reach of their grasp,

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* Nero was, perhaps, hypermetropic, but not myopic, as it is often stated. Myopia was not known in olden times, because it did not exist. Travellers have never found among uncivilized nations a case of myopia. People who do not read much, or do not use their eyes for seeing small objects, are not near-sighted. In America, which is mostly an agricultural country, there are on an average twenty-five hypermetropics to one myopic (cities excepted), while in Germany, where printing was invented, there are twenty-five myopics to one hypermetropic person. Myopia is hereditary, but decreases in a few generations when the cause for it is removed. It is, therefore, simply a temporary abnormity. Either the visual axis of the eye is too long (axial myopia), or the convexity of the lens is increased (refractive myopia); it is always acquired by habit. We could call it a *habitual anomaly* of the eye; it is of modern date, and was not known in ancient times.

The causes of hypermetropia are not at all dependent upon the abuses of the eyes by reading or doing fine work. Many natural causes produce this abnormal condition, which is certainly as old as the human race, although it has been really understood and explained only in the present century. The close resemblance of myopic and hypermetropic eyes, compelling both of them to use spectacles for seeing near and far, has wrongly caused many writers to make Nero near-sighted.

people turned their eyes to the clouds, till they lost sight of their beautiful surroundings. Unfruitful dogmas, deceptive sophistry and blind hatred were substituted for the great civilizer *Science*.

The first information of the use of a magnifying lens we find in a book about optics by *Alhazen*, an Arabian, some 900 years ago. Science at that time was like a smothered fire, with only now and then a spark faintly glowing in the ashes. Then there is another lull in the development of our interesting subject, till *Roger Bacon* made it again a special study, and even succeeded in grinding magnifying lenses himself. He was a professor at Oxford, England, and being ahead of his time in science, was misapprehended and persecuted by his contemporaries, as happened to Galileo and other men of genius. Bacon died in 1294, and it is not stated that he combined the magnifying lenses into spectacles, which we are told was accomplished about that time in Italy. We may point out *the year 1300 as the one wherein spectacles were invented*, if we ignore the pretentions of the Chinese, who claim to have known them long before that time. However, this may be, all inventions made by them were barren to the rest of mankind in consequence of their exclusiveness.

An old Latin document found at the Convent of St. Catharine of Pisa, of the year 1303, tells us that a Monk, Alexander of Spina, who died in 1313, was so skillful a mechanic that he could reproduce any kind of work he had seen, or which had been described to him; and that he made spectacles after having seen them, and the inventor had refused to communicate the true process of their manufacture. This selfish inventor was probably Salvino Armato, on whose tombstone was the inscription:

Qui Giace
Salvino D'Armati Degli Armato
di Firenze,
Inventore Degli Occhiali, MCCCXVII.

Here rests
Salvino, etc., Armato
of Florence,
Inventor of Spectacles, 1317.

The use of spectacles spread very slowly, because people had little need of them. Only a limited number of men could read, books were very scarce and very dear. Printing was not yet invented, all books were written by hand, and it was only afterwards, when their circulation increased, that spectacles came into demand. An old chronicle of Nuremberg, in Germany, of the year 1482, mentions that there were some manufacturers of spectacles in that city.

Spectacles were for a long while merely an object of curiosity, and were made use of as a novelty to improve appearance, as some years ago every "Dude," male or female, had to wear *blue glasses* for fashion's sake. In Spain they formed a part of the costume of every well-bred person. This absurd use of glasses was meant to increase the gravity of the appearance, and consequently the veneration with which the wearer of them was regarded. The glasses were proportional in size to the rank of the wearer. Those worn by the Spanish nobles were sometimes three inches in diameter. The Marquis of Astorga, when having his bust sculptured in marble, particularly enjoined upon the artist not to forget his beautiful spectacles.

After this first foolish introduction of spectacles,

which was quite contrary to their real mission of being an indispensable companion of old age and a general benefactor, there was again a period of about three hundred years in which little or nothing was said about them till some scientists, especially astronomers, experimented with the different kinds of lenses, and succeeded at last in constructing *telescopes*. The necessarily correct finish of such lenses gave a new impulse to the manufacture of spectacles, although they were made yet in limited quantity by solitary workmen, and by hand. These congratulated themselves when they could occasionally sell one pair. *Spinoza*, who died in 1677, had also learned the art of glass-grinding to make his scanty living, while he was writing his philosophical works. It is related that he made a pair of spectacles for the celebrated German philosopher *Leibnitz*, who formed his acquaintance at Haag (Holland).

From the hitherto sole occupation of opticians as glass-grinders and manufacturers of spectacle frames, they had soon to extend their vocation in proportion to the demands of science. They had not only to make spectacles and magnifying lenses, but also spy-glasses, microscopes and telescopes, and had to combine, of course, their trade with that of a regular mechanic. At last the medical fraternity came forward with their share of optical work, and it was now time to divide the trade into different branches. Some devoted their whole attention to the manufacture of astronomical instruments; others to mathematical and philosophical; others to optical appliances, and all under the collective denomination "Opticians," with the same right that Surgeons, Oculists, Pathologists and Dentists claim to call themselves "Doctors." By this division of work the public in general must profit, if every one strives to be perfect in his individual part.

It is only within the last century that our trade has risen to that great prominence it occupies to-day. We are now an indispensable factor in all scientific pursuits, and furnish instruments, not only the most scientific, but also the most useful ever offered to benefit the world. We have reason to be proud of our achievement, but we must not forget that we were merely the tools, executing the orders of scientists, who did the brain work for us, as Newton, Brewster, Herschel, Euler, Wollaston, Donders, Helmholtz, Graefe, Kirchhoff and many others, and that we have not many opticians like *Frauenhofer* to boast of. He, for instance, was a practical workman and a scientist at the same time. He gave the first impulse to Spectrum Analysis, and also manufactured flint-glass of such perfection as it has been impossible to produce since his death (1826). But alas! he was also one of those narrow-minded workmen who write on their workshop "No Admittance."

Flint-glass was known over three hundred years ago. There was as early as 1557 a factory of it in London, and English flint-glass was considered the best in the market. But they never could make pieces of more than a few inches in diameter, suitable for astronomical purposes, till Frauenhofer astonished the world with a lens of almost a foot in diameter, which was set afterwards into a refractor for the observatory at Dorpat, in Russia, and is yet in use. The difficulty is that the great quantity of lead in flint-glass cannot be equally distributed throughout all parts of the lens. Frauenhofer took his secret with him into the grave.

The spectacle business advanced considerably after the oculists detected the asymmetrical refraction of the cornea, called *Astigmatism*. Thos. Young, of England, made the first studies in astigmatism in 1793, but it was little noticed by his contemporaries. It was only after

Donders, Javal, Knapp, Helmholtz and others, more than fifty years afterwards investigated it, and explained the method of its correction by means of *cylindrical lenses*, that it was generally understood. The manufacture of such cyl. lenses with all their combinations, and especially their *correct setting*, was a new departure in our trade, and many opticians were considerably troubled before they fully mastered the difficulties in connection with this most delicate correcting medium in the shape of spectacles. A competent optician of 1860, falling asleep like *Rip Van Winkle*, and awaking to-day, could not fill the simplest order of an oculist, but would have to learn his trade over again.

As long as the selection of spectacles was left to the opticians, they contented themselves with the correction of a limited number of defects, and declared the balance incurable. They did not know the nature of irregularities, such as Hypermetropia, Astigmatism, etc., and were, therefore, totally in the dark about their correction. Oculists formerly considered it beneath their dignity to have to do with spectacles, and after they had restored the injured or suffering eye to a healthy state, they turned the patient over to an optician for the proper selection of glasses, unconcerned whether this selection was a good or bad one. It is only since Donders, Helmholtz, Graefe and others investigated such "incurable" cases, that they are understood, and can be thoroughly corrected by spectacles specially adapted. Although such spectacles are manufactured by opticians, the credit of their beneficial action belongs to those eminent explorers who gradually wrenched their selection from the hands of mostly indifferent mechanics, who destitute of the necessary scientific education, have to satisfy themselves with a secondary position under the leadership of the oculists. There is no blame attached to our

present position, as it is not at all a step backward. On the contrary, the standard of our trade has advanced considerably, but it has not kept step with the gigantic progress of Ophthalmology, which has no equal in medical history. In the last twenty-five years Ophthalmology and general Surgery have become exact sciences, while the rest of medicine is yet for the most part empirical, as was the case with our mechanical and hap-hazard manner of selecting spectacles, when the patient was the principal judge of their correctness.

The selection of spectacles in complicated cases is now the exclusive dominion of oculists, who are, as physicians, qualified to *prepare the eye* for a thorough examination. Any optician, tampering with the eyes of an easily frightened customer, may cause himself great trouble if he cannot legally attach to his name an M. D. Only cases of simple presbyopia, manifest myopia and hypermetropia can be properly investigated by an optician, because the other and more complicated errors of refraction require that the ciliary muscle (accommodation) be temporarily paralyzed by a mydriatic, as atropia; and that in this state of the eye accurate and repeated measurements be made with test-types and trial lenses. Signs in the windows of opticians which read: "Examinations of the eye made free of charge," smack of quackery, and should be removed.—We have here to record also the meritorious invention of Jaeger and Snellen, whose test-types are so universally in use at present.

Among all the men I have mentioned, there is no *American;* and we must concede that as to the theory of our trade, Europe is ahead of us. But as to the practical part, we have in the short space of the last twenty-five years outdone all former efforts of Europe. Before that time most spectacles were imported from France,

England and Germany; but lately we only import the lenses, and I may predict that in less than another quarter century this importation will have ceased, as well as the former brisk *trade in European watches*, which has been stopped entirely by the superiority of our own manufacture. We may be proud of our well-earned success, and I am not astonished when our people return from Europe, telling the gratifying news that their glasses with the latest improvements, were admired by every European optician who had seen them.

In concluding this chapter, let us devote a few lines to the origin of the different names under which spectacles are known. The English word "*Spectacles*" is derived from the Latin word *spectare*, to look at, to behold, and is used always in the plural on account of the two glasses of which they consist. The French word "*Lunettes*" comes from the word *lune*, moon; and lunettes means *little moons*. Spectacles were first made round, and although they were changed now and then according to fashion, the round shape survived all other patterns down to recent date, since which it has been superseded by the oval shape. The German word "*Brille*" is derived from *Beryl*, a transparent greenish-bluish mineral, called by the jewelers Aqua Marine. The Latin name for it is Beryllus, and signifies to shine or sparkle. The word *Brilliant* is also derived from ~~Brille~~, but is now used only in reference to diamonds. In former years people in Germany called all colored glasses "Berylle," and as a great many spectacles, especially those worn for fashion's sake, were set with plain colored glasses, this optical instrument received its name from that mineral.

Beryl

MISCELLANEOUS APPENDICES.

A.—How to Relieve An Injured Eye.

This article is not altogether my own, but is partly compiled from different sources. It would not have found a place here if it were not for the great usefulness of these simple directions in case of emergency. Though the eyes are well protected and shielded by the forehead, the nose-bridge and the cheek-bones, they are nevertheless much exposed to accidents caused by flying objects; and although the eyelids are the most reliable safeguards to keep off any foreign intruders, they may be out-generaled occasionally, when they are the least aware of any danger. Some injuries do not allow of any delay, and as medical assistance is not always to be had when mostly needed, I thought it proper to add this treatise not only for the personal benefit of my readers, but also for that of their friends and customers, who may in their trouble come running to the optician as the next proper person to give them relief. I was several times successful in this regard, and may say that I saved more than one eye from great annoyance and danger.

A very common accident is the flying of *mud*, *dust* or *insects* into the eye, which, by the closing of the eye, enter between the lid and the eye-ball. People thus affected generally keep their eyes closed, as the opening of the lids causes such an irritation that the eye-ball is soon inflamed, and turns red and bloodshot. The quickest way to relieve those sufferers is to wash the dirt out

with clean water by means of a camel-hair brush or a feather. This is done in the following manner: With our left hand we take hold of the eye-lashes of the upper lid, drawing it forward enough to allow the brush or feather, previously dipped in water, to enter between the eye-ball and the lid, till we reach the inner folds. We direct the patient to look downward, and move the brush towards the nose, not to the outside. We have to repeat this several times with plenty of water. Then we depress the lower lid, directing the patient to look upwards, and wash carefully as before, cleaning the brush after each application. In some trifling cases, when an insect or a few grains of dust have entered the eye, it is sufficient to draw the upper lid as far down as possible, and a little outward, and push the lower one as far up as you can. Then let the upper lid fly back to its natural position, when the eye-lashes of the lower one will act as a brush, detaching any light substances, and relieving the eye instantly. Make it a rule never to rub the eye when injured, as the irritation will be increased largely by it, and soon will cause inflammation. When hard pieces are imbedded in the tender parts of the conjunctiva, which cannot be removed by the brush, it is not difficult to remove them if they are lodged in the lower lid, by means of a handkerchief or some small pincers; but it requires some skill to remove them from behind the upper lid. In order to accomplish this, we have to evert the same, which is done by taking a good hold of the eye-lashes and the edge of the lid with the left hand, and applying with the right hand a thin pencil or any other rounded object to the middle of the lid, and by depressing the pencil, and at the same time swinging the left hand upward, the lid is everted and the inside exposed for examination. The patient is now directed to look downward, which brings into view the whole

inner surface of the upper lid, and enables us to remove any foreign bodies, as grains of sand or bits of coal, yet sticking in the soft part of the tender tissues.

Mechanics are very often hurt by flying *particles of metal* while hammering or turning, and chips may strike and penetrate to some extent the front part of the eye. If these are of iron or steel, and not imbedded too deep, we may remove them by the use of a strong magnet. In case these chips have penetrated so far that the conjunctiva has closed over the entrance of the wound, it is necessary to consult a physician. Such wounds are not very painful at first, and the application of water or oil may be sufficient to allow us to wait even until the next day to look for relief. Any longer delay may prove fatal, as a neglect will surely result in a violent inflammation, if these particles are not removed in due time.

Another danger to the eyes is the splashing of *quicklime* into them, causing sometimes the complete loss of sight. I myself was a victim of such an accident at the age of four years. Some workmen were slacking lime, and I was wondering how stones covered with water could boil. Wholly absorbed by this phenomenon, one mischievous boy gave me a push, and I fell headlong into the hot lime water, but was immediately rescued, washed and brought to bed. I soon felt that something soothing was applied to my eyes, which relieved them of the burning sensation. It was three weeks before I could open my eyes again, and I remember very well the many anxious inquiries of my parents, whether I could see them. In such accidents, the lime should be instantly washed with water and vinegar as thoroughly as possible, and a rag saturated with sweet-oil applied, till a physician can be consulted.

If *corrosive pigments and acids* enter the eye, the whole face, eyes open, should be repeatedly dipped into

water in order to dilute and wash off the acid or paint; then apply freely milk, and afterwards plenty oil, till medical assistance can be procured. Whatever is done must be done quickly, as it is of the greatest importance to relieve the eye instantly from the ravages of such corrosive substances.

In case the eye should be *scalded* or injured by the spattering of hot fluids, do not apply water, but only oil or milk, and shut off light and air by a compress of soft linen, thoroughly wet with sweet-oil, till the doctor comes.

These directions are not intended to do away with the services of the physician. On the contrary, they are intended only to prevent as much as possible the pernicious consequences and further progress of such accidents, till professional aid can be procured. Sometimes five minutes' delay is sufficient to destroy eyesight forever, when by the prompt application of water, vinegar, milk or oil, the effects of such injuries would be diminished, and oftentimes removed entirely.

B. — How Far Can We See?

When any-one draws the attention of his companions to a distant object, there is likely to be at least one among them unable to perceive anything, although the others see it well. He may be near-sighted, or have some other defects of vision that will prevent his seeing at a distance. But those who saw the object clearly on that day are perhaps unable to discover it on another, when the atmosphere is cloudy. This is the reason why it is almost impossible to decide the above question with mathematical precision. In undertaking to give some

valuable information about this apparently perplexing subject, I presuppose that the eye is emmetropic (perfect); that the atmosphere is clear; and that the object we endeavor to discover is of a color readily distinguished from its surroundings. *These three conditions fulfilled, we can see an object which is not farther away than 5000 times its diameter.* If a stick is 10′ long but 1″ thick, its diameter is only 1″, and it can be seen at a distance of 5000 × 1″ = 417′. The length is not considered in the calculation. A wall may be 1 mile long, but only 4′ high; then 4′ would be the diameter. We could see it on a clear day at a distance of almost 4 miles. Distant vision is mostly favored by the summits of moderate mountains. The atmosphere is clearer there than on the plains, and vision is not obstructed by the unevenness of the ground.—This rule can be applied to some practical use. A clock-maker, for instance, receives an order for a tower clock with a dial large enough to render the numbers visible at a distance of 3000′; how large must the dial be? To distinguish the hours at that distance, we must be able to see the hands. How broad ought they to be? One foot can be seen 5000′ away. We find by calculation that their breadth must be 7″, at least at one point; (our eye will readily form the connection of this point with the centre); and that the length of the numbers must be 15″. The diameter of the dial is generally 6 times the length of the numbers. It should, therefore, be 7½ feet wide.

According to this rule, we can find, approximately, the distance of any object, if we know its size; or its size, if we know its distance. The breadth of a man is 1½′. If we can barely see him, he is 1½ × 5000′ away, or almost a mile and a half. If he is dressed in white, and the surroundings are dark, the distance may be set at 1¾ miles; if dressed in black, it may be only 1 mile.

Here it is again seen that the rule must be modified according to the contrast of the *colors* of the objects.

If the back ground is dark, the impression of the different colors upon our eye range in the following order: White, yellow, orange, red, green, blue, violet and black, i. e., black disappears first, then violet, etc. White on black makes the strongest impression, and is seen the farthest. Upon a light-colored back ground the effect is the reverse, with the exception of violet, which disappears before red.

It is a well-known fact that all animals of prey bear the color of their hiding places. This enables them to surprise their booty without being seen from any distance. The striped tiger in the Indian swamps or jungles resembles the environs so perfectly that his victim is not aware of his presence till it is too late. The yellow stems of the reeds, and the darker ground, produce a striking resemblance to the skin of this voracious beast. This curious play of nature is called "mimicry," and benefits not only those beasts, but also many animals which are preyed upon.

The hunter is thus sorely vexed, and often cannot make use of the above rule. But in military life there are many occasions where it is of an immense importance, by furnishing an estimate of the number of the advancing foe, and giving time to prepare for their reception.

There arises another question analogous to the previous one. I refer to the fact that it is so very difficult to judge with any certainty the number of people congregated in large assemblages.

It requires only little practice to judge also about such numbers of a vast throng or concourse of people in a street row, in a tumult, or at a public meeting. But the many extravagant and contradictory reports after such

an event are a good proof of the incorrectness of the judgment generally exercised in this regard. The easiest way for this kind of calculation is to measure the ground in square feet, and divide the number by 4, as 4 square feet is ample room for a standing person. We can measure a space by walking over it and counting the steps. A full step (not a stride), measures on an average $2\frac{1}{2}'$. Suppose, at a public meeting well attended, the bulk of the crowd extends in one direction 60 paces (150′); in another, 30 (75′); we have then $150 \times 75 = 11{,}250$ square feet, divided by 4, gives 2812; and with the stray people counted in, we may estimate that about 3000 persons were attending the meeting. The next day we will read in the different papers that the attendance was immense, and that there were at least 5000 persons present. Others will exaggerate the number even from 8000 to 10,000. These mistakes would not happen if we only made use of the rules laid down in this short treatise.

C. — Why Do We Shed Tears When We Weep?

The eyes of all vertebrae, with the exception of fishes, and those amphibious animals that live in water, are provided with tear-glands, to moisten the surface of the eyes and the inner side of the lids. If the tears were stopped, the outside of the eye-ball would become dry and opaque, and sight be lost. As long as the tears flow, they are drained through the tear-duct into the nose, and here mostly evaporate without any further annoyance. But if in consequence of catarrh or other cause, these tear-ducts are closed, the eyes fill with water which runs down the cheeks in the form of tears. This occurs in the eyes of men as well as of animals,

but we cannot call it "weeping;" it is only an overflowing of the fluid from local and physical causes.

No animal weeps. Real weeping presupposes *mental emotion*, based on self-consciousness. Only human beings can reflect upon their own existence, and contemplate themselves in an objective way. Without this great superiority over the animals we would be unable to touch that responsive chord of our spiritual existence which makes us weep for joy, grief or pain.

The irritation for weeping originates in the brain, and is conducted from there by a separate nerve to the tear-glands, causing a profuse secretion of moisture. For instance, some impudent individual wounds the tender sensibility of our feelings, and unable to chastise him on account of his rank, power or position, we are overcome by our impotence and mortification—rage fills our eyes with tears. A woman weeps sooner than a man; her feelings are more easily hurt; she belongs to the weaker sex, and in her desolate, fainting mood, sometimes over imaginary troubles and grievances, she weeps heart-brokenly. Children and silly persons very often cry because they set great value on trifling objects, whose refusal makes them extremely unhappy.

But weeping is not always a sign of weakness, or an object to be ridiculed. The greatest men on earth had moments of mental agitation which made them weep; and while listening with awe to the story of their affliction, we unconsciously reach for our handkerchiefs to dry our eyes. We are overcome by a certain feeling, which is another prerogative of the human race—sympathy. The power of weeping is frequently a great blessing; it calms and cools our over-heated brain, and may prevent even serious incidents. As the opening of a valve saves the boiler from explosion, so tears gradually melt away

that rock which rests upon our breast, and threatens to choke us by its insupportable weight.

D.—Different Expressions of Faces, Based Upon the Position of the Eyes.

The common saying, that "A good face is the best recommendation in life," is not based solely upon the good looks or the fine appearance of a person, for this has little to do with the favorable impression we make, at least upon our own sex. It has a deeper foundation for its truth, which is not generally known. How often do we meet persons with plain faces, and even irregular features, and yet are fascinated by them, although their discourse is not marked by brilliancy of eloquence or depth of knowledge. We have been captured by them without knowing how? It is the witchery of an *expressive* eye that has conquered us; and this is the only explanation of the spell exercised by such persons upon their surroundings.

A close observer of the facial expressions of different individuals will find the greatest variety in their delineation, based upon the direction of the axis of vision. In children this axis is almost constantly parallel, producing the impression of thoughtlessness, or of the childish innocent look. With increasing intelligence the eyes lose their parallelism by being fixed upon objects of investigation. All the affections of the mind are now manifested by certain motions and positions of the eyes, which become more convergent. The lurking look of the convict on trial; the watchful scrutiny of the over-suspicious; the piercing glance of anger; the lustful look of the libertine; the rude gaze of the ruffian, and

the fearful glare of the maniac, all are modifications of the same act, produced by an increased convergency of the axis of the eyes.

The gentle and refined affections of the mind restore to a certain degree the parallelism of the axis. It is this that appeals in the eye of the trusting; sparkles in the eye of the happy and the gay; subdues in the look of the affectionate and the loving; awes and elevates in upward gaze of piety and religion, or composes in the gentle regard of the devout and resigned.

The eyes of a frightened person even diverge; the wish to be far away from the place of danger causes this spreading of the pupils and opening of the eyelids.

In old age the axis of vision again becomes parallel. The passions of former years are calmed, and the mind, in a contemplative mood, is now diverted upon its future distant home. At last the eye dies in the absolute parallelism of the axis of vision.

E.—Refraction and Dispersion of Light.

Light always travels in straight lines; it is interrupted in its direction only by entering a medium of different density from that through which it previously moved. This change of the rays of light from their direct course is called the *refraction* of light. Glass, water and all transparent bodies and fluids have this power of refracting the rays of light, but the relation of the *angle of refraction* to the *angle of incidence* varies with the nature of the different media, each of which has a distinct power. The ratio or proportion between them is called the *index of refraction*. For different media, it is as follows:

Air	1.000
Water	1.336
Oil of Turpentine	1.475
Crown-Glass	1.538
Rock-Crystal	1.548
Flint-Glass	1.633
Strass or Paste	2.028
Diamond	2.439

In this table, air is taken as the unit of comparison. The refractive power of crown-glass and pebbles is almost the same; flint-glass shows a considerable increase, strass more so. This is also a flint-glass, with a larger proportion of lead, and is known as the "extra white." The high refractive power in diamonds causes that sparkling clearness called "first water," and is valued by all connoisseurs of precious stones. Spectacle-glasses made of diamonds would be injurious to the eyes on account of this glaring refractive power.

The refraction of the rays of light passing from one medium to another causes also the separation of light into its different colored rays. This is called the *dispersion* of light. We have seen that refraction refers to the change in the direction of the rays, while dispersion relates only to colors, produced by an unequal bending of the rays of light. The dispersive power also varies in different bodies; air is, of course, excluded, as we have no means of finding the index of its dispersion, if there is any.

Rock-Crystal	0.026
Water	0.035
Crown-Glass	0.037
Oil of Turpentine	0.042
Flint-Glass	0.049
Diamond	0.056

This table of the index of dispersion shows clearly the superiority of *pebbles* over any glass, because the eye is most benefitted by lenses of the lowest power of dispersion. If spectacles were set with achromatic lenses, like the objectives of spy-glasses and opera-glasses, they would be the best ever made; but nobody could carry such a weight on his nose; besides, the high price of such lenses would permit only a limited sale, and therefore no optician could keep an assortment of them in stock.

The high dispersive power of diamonds causes that fascinating display of beautiful spectral colors called "first fire," but it renders this mineral at the same time utterly unfit for spectacles, even if some people were rich enough to pay for them.

F.—Conclusion, Containing Some Practical And Useful Remarks.

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1. To Redress Spectacles. In order to save time and trouble, we should invariably commence with the nose-piece in connection with that eye which is the nearest correct. We should then bend the other eye so, that both form a perfect plane, or that they stand in a straight line. Beginners do well to provide themselves with a small ruler about 3 inches in length, and use it as a test by placing it flatly on one eye, observing whether the other one is in the same plane. Then put it edgewise over the middle of one eye, from temple to nose-piece, and see whether the other glass is not too high or too low. When the middle part is corrected we examine the temples, and straighten them without paying any attention to the position they will have in relation to the centre part. If one of them extends too far to the outside,

we should loosen the screw, or better, take out the glass altogether, and bend the joint upward, thus bringing the temple to a right angle with the centre. It remains now only to give the finishing touch to the temples. If one of them stands lower than the other, the lens on that side will be raised to the greatest disturbance of the vision. To correct this, we close both temples, and see which one points exactly to the opposite joint; we take this as the model, by which we correct the other one. We cannot do this by bending the temple itself up or down, for this would undo a former correction, which consisted in straightening the temples "without paying attention to their position." A little reflection soon convinces us that the fault is not with the temple, but with the joint. In order to bend the joint, we must take a good hold of it with some blunt cutting-pliers nearest the eye, leaving almost the whole length of the joint at our disposal, and by means of strong flat-pliers we can bring the joint to its proper position without any risk. Any bending of spectacles should be done always with two pliers, one in each hand. In addition to the above, we also need round-pliers, especially in redressing the nose-piece. To ascertain finally the correctness of our work, we must lay them edgewise upon a flat surface, as the show-case, and see if the ends of both temples touch the glass; if it does not, we have to go once more over the whole line of the aforesaid manipulations.

2. To Increase the Strength of a cx lens, it is necessary to remove it from the eye. With a concave lens it is the reverse; its removal from the eye makes it weaker. A cc lens is strongest the nearer we approach it to the eye.

3. Direct Vision is that which pertains to the macula; that which belongs to the rest of the retina is

called *indirect* or *peripheral vision*. Indirect vision, although it may be very indistinct and imperfect in comparison with *central vision*, is, however, not less important than the latter. Without peripheric vision we would be in the condition of a man looking through a long, narrow tube which would allow of his seeing nothing but the object to which the axis of vision was directed. It would be impossible for him to see objects to one side without an incessant turning of his head. (*Landolt.*)

4. The Base of a Prism should be always turned in the opposite direction to that in which the eye is deviated: strabismus divergens = base in, convergens = base out.

5. The Axis of Cyl. Glasses should be placed at right angles to the meridian we intend to correct. If the eye sees objects indistinctly in the vertical line, place the axis of the correcting cyl. lens horizontally, or always 90 ° from the faulty meridian.

6. The Different Kinds of Spherical Lenses.

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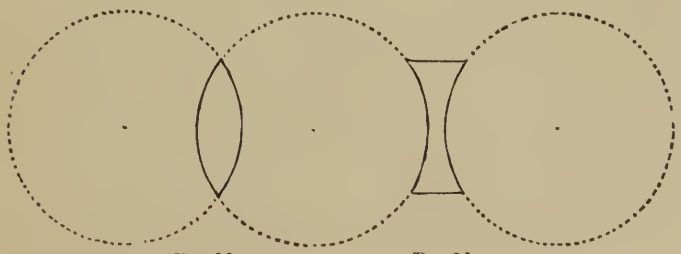
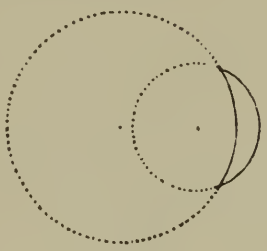
Double cx or cc, both curves are segments of two equal spheres.

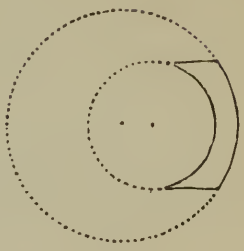


Double cx. *Double cc.*

Periscopic cx or cc, the two curves are formed by spheres of different sizes.

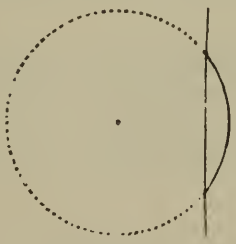


Perisc. cx.

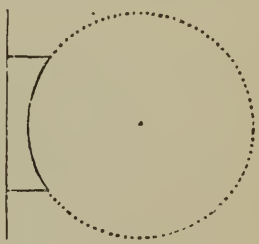


Perisc. cc.

Plano cx or cc, formed by a plane and one sphere. The plane is either inside or outside of the sphere.



Plano cx.



Plano cc.

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